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August 2003

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Ultra-High Transmission Coatings (UHTC) Group: 6" models – $85; 8" – $125; 10" – $150.

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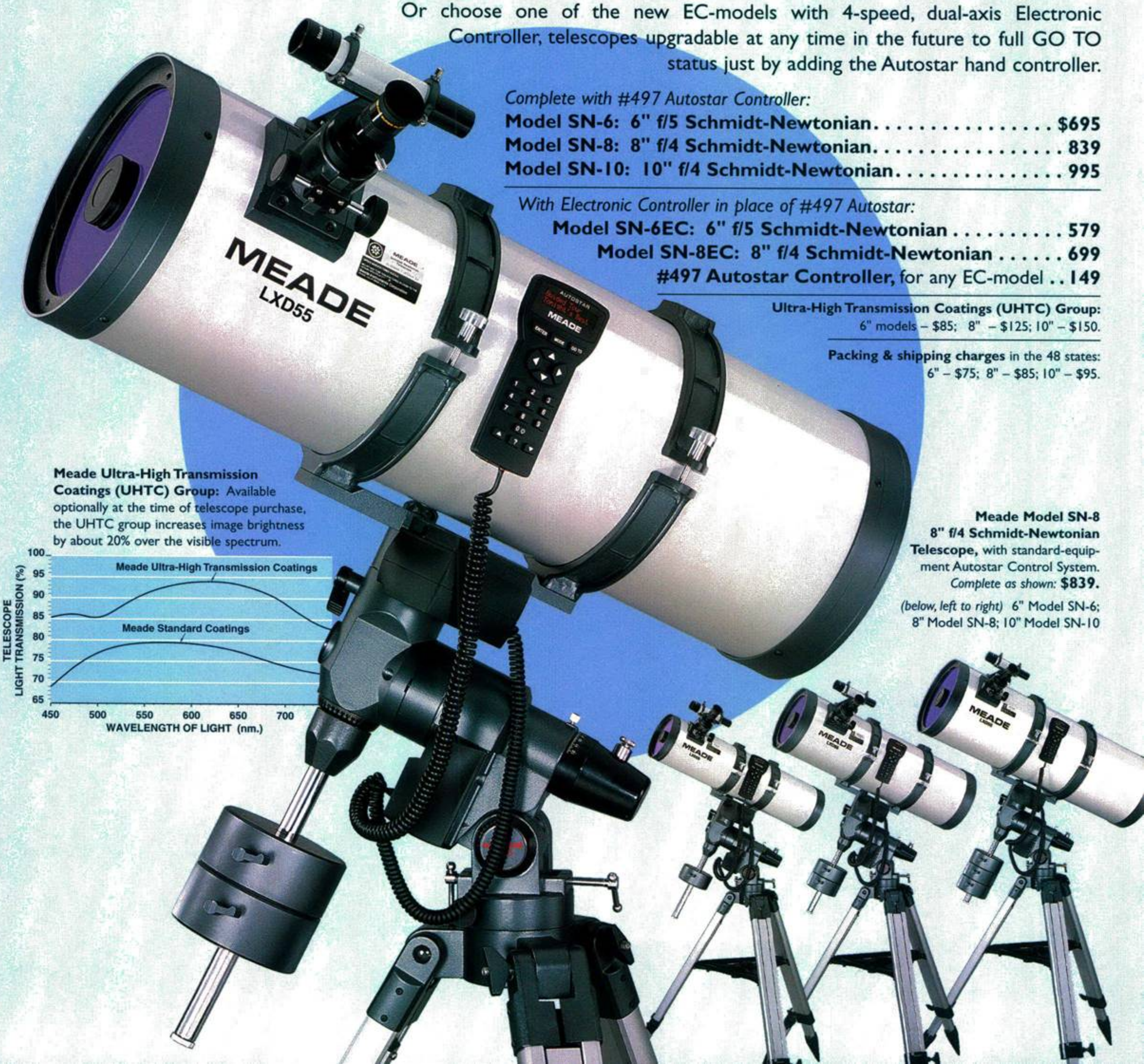
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LXD55
AUTOSTAR
MEADE
ENTER
MODE
GO TO
100
95
90
85
80
75
70
65
TELESCOPE LIGHT TRANSMISSION (%)
Meade Ultra-High Transmission Coatings
Meade Standard Coatings
450
500
550
600
650
700
WAVELENGTH OF LIGHT (nm.)

Meade Ultra-High Transmission Coatings (UHTC) Group: Available optionally at the time of telescope purchase, the UHTC group increases image brightness by about 20% over the visible spectrum.

Meade Model SN-8 8" f/4 Schmidt-Newtonian Telescope, with standard-equipment Autostar Control System. *Complete as shown:* **$839.**

(below, left to right) 6" Model SN-6; 8" Model SN-8; 10" Model SN-10

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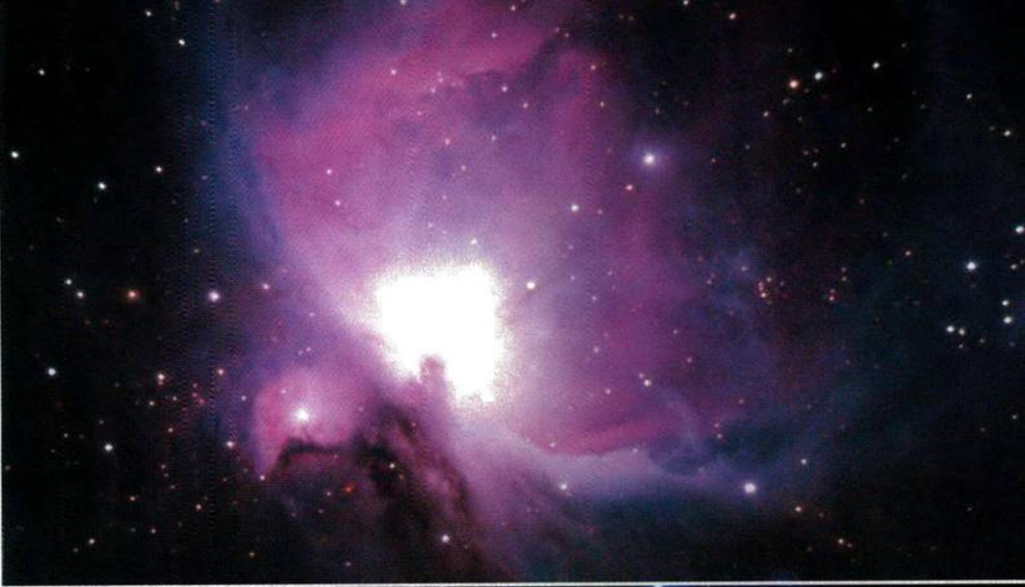
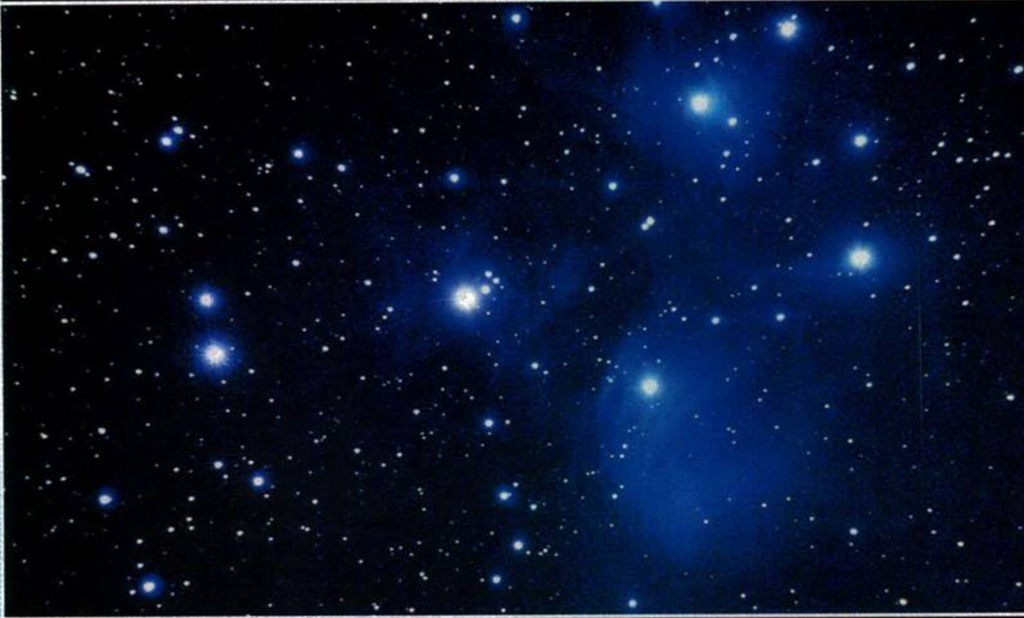
Images with the Meade Model SN-8 8" f/4 Schmidt-Newtonian telescope. To obtain the images at right H. Tokumitsu attached a Fuji FinePix S2Pro digital camera to the eyepiece-holder of his unmodified, factory-standard Meade Model SN-8. Tracking was accomplished on the LXD55 equatorial mount with the telescope's R.A. drive at the sidereal rate; no guiding was performed during the period of the exposures. *(top to bottom)* **The Great Nebula in Orion (M42)**; a composite of two 3-minute exposures. **The Pleiades (M45)**; a composite of two 2-minute exposures. **The Andromeda Galaxy (M31)**; a composite of four 3-minute exposures.

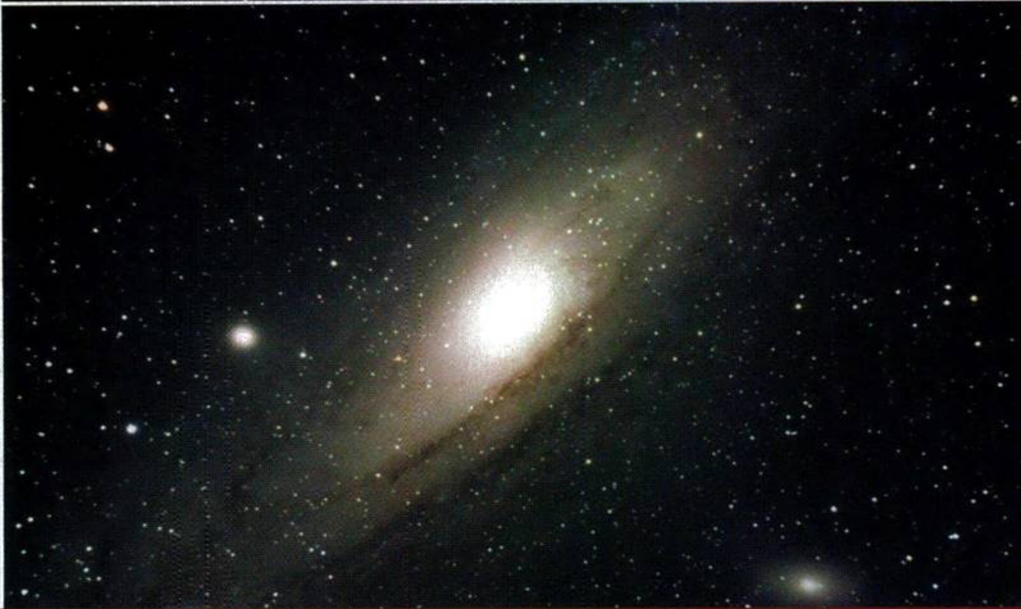
Many amateurs have used Meade LXD55-Series Schmidt-Newtonians to obtain stunning images of the Moon, planets, and deep-space with commonly-available consumer digital cameras. Meade "fast" flat-field optics, combined with smooth worm-gear tracking systems and the Autostar controller, permit even the beginning amateur to obtain images like those at right.

"Here in Japan, where Meade is the number one Schmidt-Cassegrain brand by a large quantity, your new LXD55 Schmidt-Newtonians have received a lot of attention. My personal choice was the 8" f/4 model, and I have been extremely pleased with the telescope in every respect. The equatorial mounting is solid and vibration-free for both high-magnification visual observing and for astrophotography. The optics are excellent, with sharp, round stellar diffraction images across the large field of view, and without the coma visible in fast parabolic Newtonians. Not only does the telescope give incredible views of deep-space objects and star fields, but it is a fine lunar and planetary instrument as well. Jupiter shows numerous cloud belts with a great deal of structure within the belts; Saturn's ring divisions and disk markings are very nicely resolved.

"My latest application of the 8" LXD55 Schmidt-Newtonian is to image deep-space objects with the Fuji FinePix S2Pro digital camera. Although this camera was developed as a consumer product, not as an astro-imaging device, the results I have obtained are most rewarding. I am enclosing a CD-ROM of some of my images. All images were obtained simply by attaching the camera body to the telescope, exposing ***unguided*** *for 2 to 3 minutes, and then compositing several images. In my 20 years as an amateur astronomer I have never obtained such impressive results with so little effort!* **— H. Tokumitsu, Tokyo, Japan.**







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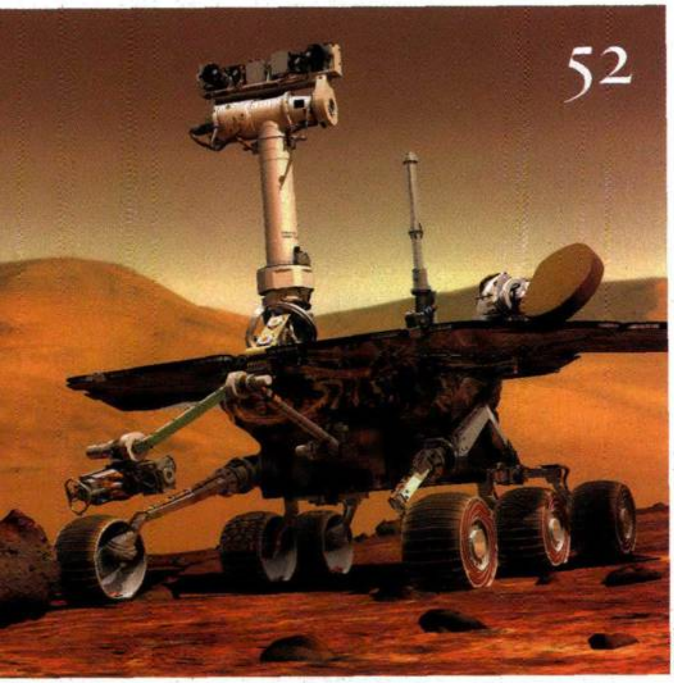

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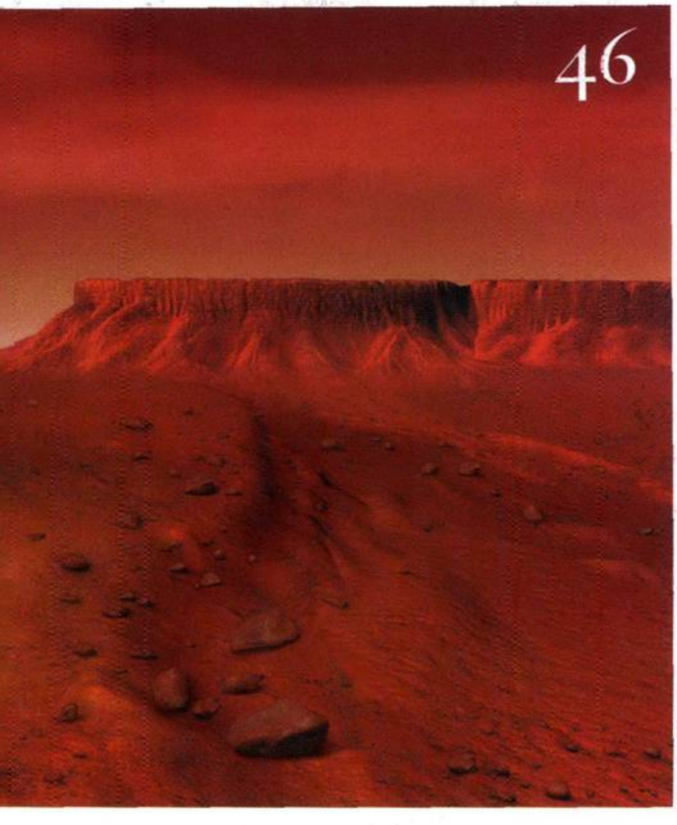

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During four centuries of earthbound observations, astronomers seeking detail on the Red Planet found plenty — much of it real, some of it imagined. GEOFF CHESTER

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Tattooed with craters and gullies, this dusty planet holds secrets of a wild youth. Scientists are studying the scars to piece together Mars's active past, which may not have ended as long ago as we think. WILLIAM K. HARTMANN

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52 Blazing a new path

With a single goal — to test the hypothesis that Mars once had an earthlike geology, climate, and maybe even biology — the Mars Exploration Rovers are set to rove NASA into a new era of planetary exploration. JIM BELL

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Stunning star clusters, picturesque planetary nebulae, and glittering galaxies lend some of the Milky Way's sparkle to the Wolf and Carpenter's Square. TOM POLAKIS

PLANETARY OBSERVING

80 Get ready for Mars

After all the previews, build-ups, and prognostications, the time for observing Mars at its best finally has arrived. Use these helpful hints to get the most out of the time you and Mars spend at the telescope during the next few months. MICHAEL E. BAKICH

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Get the most detail out of your sky views by using color filters. In this how-to, we introduce you to the filters best suited to your favorite planets. PHIL HARRINGTON

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92 Imaging the Red Planet

The great opposition is this month, and you have a brand-new CCD to take wonderful images. But do you have the know-how? One of the world's great planetary imagers details how you can produce breathtaking images with your CCD. DON PARKER

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96 An upgraded classic

The LXD-55 series combines classic looks with cutting-edge computer technology. Find out if this is your next purchase as *Astronomy* field-tests a new line of Schmidt-Newtonian telescopes from Meade. STEVE EDBERG

MARVIN NAUMAN

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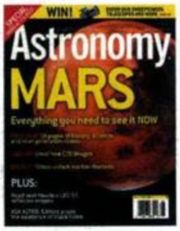

ON THE COVER

The Red Planet glows vibrantly in a U.S. Geological Survey mosaic image created from Viking spacecraft Mars imagery. The large, dark feature at right is Syrtis Major; the prominent basin below it is Huygens. The frost-laden edge of the Hellas Basin lies at bottom, along what appears to be the planet's limb. USGS

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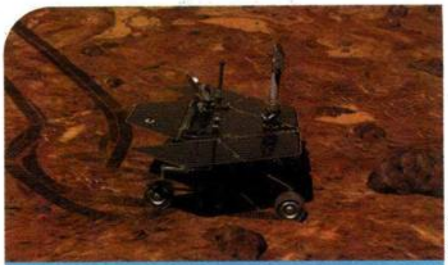

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MARTIAN CHRONICLES: Mars's role in pop culture

MARTIAN TIME LINE: Narrating the Red Planet's history through its geology

ROVING ON MARS: Animations to take you there

OBSERVING MARS: More viewing tips, guides, timetables, maps, and other tools

SAY CHEESE: Amateur shots of Mars

Astronomy.com

BY DAVID J. EICHER

The Red Planet takes center stage

After what seems like a lifetime of hype, Mars has finally taken over as the astronomical show of the year. Just about every two years, the Red Planet comes to opposition, but this year — on August 27 — the best martian opposition in more than 50,000 years will occur. The event will place Mars larger and brighter in Earth's sky than we will ever see again. Mars mania will sweep the astronomy world, and it's likely your friends who have never looked through a telescope will ask to gaze at that neighbor world with so much lore attached. You can be a good ambassador to the hobby of backyard astronomy by hosting a Mars party and showing everyone what all the fuss is about.

But don't wait too long. Observing the Red Planet on the early end of an opposition is a good idea because there's always a chance that as Mars approaches the Sun, rising heat will initiate a global dust storm, obscuring the surface features visible in telescopes. For a complete guide to viewing the opposition, see "Get ready for Mars" by associate editor Michael E. Bakich on page 80.

On another matter, the editors and art staff of *Astronomy* are keenly sensitive to what you, the readers, think. We are elated at the tremendously positive response to the new magazine, its coverage, photography, expanded hobby articles, and tight science focus. Along with positive feedback, we also received some requests to make the typography easier to read. Alas, we are all aging — even astronomers.

We have changed the primary font, starting with this issue, to a bolder typeface. Numerals and fractions also will be easier to read now. We have removed the "numerical clock" from the page numbers, a design artifact, and reinstated conventional pagination.

COPY EDITOR LAURA BAIRD joins the *Astronomy* staff. *ASTRONOMY*: WILLIAM ZUBACK

Finally, welcome Laura Baird, our new copy editor. A meticulous reader and burgeoning astronomy hobbyist, Laura is a graduate of the University of Minnesota–Twin Cities and Loyola University in Chicago, where she earned bachelor's and master's degrees in history.

In addition to science courses, including astronomy, Laura studied French, Latin, and Old English while a student. Laura is excited to bring her skills to the magazine.

Yours truly,

Dave Eicher
Editor

Astronomy
VoL. 31 No. 8

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Worm gears of 4.9"-diameter on both telescope axes for smooth sidereal-rate tracking of celestial objects as well as precise guiding corrections during long-exposure imaging.

Die-cast-aluminum *double-tine* fork mount that rigidly supports the optical tube in all sky orientations.

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Autostar™ Computer Controller: The LX90s *standard-equipment* Autostar controller permits an incredible array of telescope features:

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  - 13,235 deep-sky objects — the complete Messier, Caldwell, IC, and NGC catalogs; 16,888 stars; the 8 major planets; the Moon; 26 asteroids; 15 comets; 50 Earth satellites; plus 200 user-defined memory locations.
- *Automatic GO TO capability* to any object of known R.A. and Declination. Plus hundreds of special event menus, guided tours, utility functions, and telescope status options.
- *Nine selectable slew speeds:* 6.5°/sec, 3°/sec, and 1.5°/sec, as well as 128x, 64x, 16x, 8x, 2x, and 1x sidereal.
- *Control of the telescope through your personal computer.* (Requires optional #505 Connector Cable Set.)
- *Fast alignment of the telescope* using any of three alignment functions, including the Meade-proprietary Easy Align.
- *Autostar is fully upgradeable over the Internet:* add the positions of new comets, update the positions of Earth satellites, even add new software.

With diffraction-limited optics in an Autostar computer-controlled telescope system, the Meade 8" LX90 includes capabilities not available on other brands of 8" Schmidt-Cassegrains costing hundreds of dollars more. Incorporating the optical system of the 8" LX200GPS, and with 5 arc-minute pointing precision in the GO TO mode, the LX90 is fully qualified for long-exposure CCD imaging and astrophotography as well as for other advanced photo-visual applications.

8" LX90
Schmidt-Cassegrain
$1495

SPECIFICATIONS: 8" LX90 — Each complete telescope includes 8" f/10 Schmidt-Cassegrain optical tube assembly with MgF_2 coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally; see below); double-tine fork mount with dual-axis 4.9" worm gears and control panel; electric slow-motion controls on both axes; Autostar hand controller with digital readout display, 9-speed drive controls on both axes, and GO TO controller; 30,223-object onboard celestial software library; internal battery port accepts 8 (user-supplied) C-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); 8 x 50mm viewfinder 1.25" diagonal prism; Series 4000 Super Plössl 26mm eyepiece; standard field tripod operating instructions. **$1495. Ultra-High Transmission Coatings (UHTC) group** increases image brightness by about 20%: add **$175.** Packing & shipping in the 48 states: $95.

The Meade 8" LX90 is manufactured under U.S. Patent Nos. 6,304,376 and 6,392,799; other patents pending in the U.S.A. and worldwide.

Buy a $650 Super Plössl eyepiece set for your LX90 telescope for only $99! ***See ad on page 8 for details!***

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Choose from more than a dozen qualifying Meade telescopes *(see listing at right)*, mail us your check for $99, and we'll ship your Super Plössl eyepiece set directly to you. And we'll pack your eyepieces in the Meade #771 foam-lined aluminum carrying case, itself a $49.95 value if purchased separately. For complete details see the HOW TO ORDER box at right.

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SP26mm	(standard equipment)**
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SP40mm	99.95
#771 Aluminum Carrying Case	49.95
Total price if purchased separately:	**$649.60**

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ETX-90AT Astro Telescope	**$595**
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Alternately, for the beginning-to-intermediate observer, the ETX-70AT is supplied with #494 Autostar Controller and #882 Field Tripod:

ETX-70AT Astro Telescope	**299**

Packing & shipping (ETX, Autostar, & Tripod): ETX-90AT — $30; ETX-105AT — $35; ETX-125AT — $40; ETX-70AT — $20.

Meade ETX-125AT
Shown with standard-equipment #497 Autostar Controller and #884 Deluxe Field Tripod.

Buy a $650 Super Plössl eyepiece set for your ETX telescope for only $99! ***See ad on facing page for details!***

New 2003 Meade General Catalog!

Call, write or fax for your free copy.

ADVANCED PRODUCTS DIVISION
Meade Instruments Corporation
The largest-selling telescopes in the world. ■ *A NASDAQ® company.*
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MEADE®

RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls
52° field; multi-coated

Meade 4-element Super Plossls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or studying tenuous nebulosity in deep-space, Meade SP's deliver unmatched contrast and image sharpness. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal. **Super Plössls** (SP; 4-elements; 1.25"; 52°): **6.4, 9.7, 12.4, 15, 20, 26mm** each: **$79.95** (4.54); **32mm** (52°); **40mm** (44°) each: **99.95** (5.26); **56mm** (52°; 2") **199.95** (7.02)

Series 4000™ Super Wide Angle
67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above. **Super Wide Angle** (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 4000™ Ultra Wide Angle
84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians. **Ultra Wide Angle** (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

#1209 Zero Image-Shift Microfocuser

Identical to the Microfocuser supplied with Meade LX200GPS telescopes, but provided with a separate handbox for use with all other Meade SCT models (e.g., LX10, LX50, LX90, LX200) or for Schmidt-Cassegrains of other brands. Threads directly to the telescope's rear cell. Permits extremely precise focusing of the image during visual or photographic applications; during CCD applications maintains precise image centration on even the smallest CCD chips. Operates at four speeds, from extremely slow to fast; accepts both 2" and 1.25" eyepiece barrels. Requires 8 x AAA (user-supplied) batteries. **$249.95** (9.85)

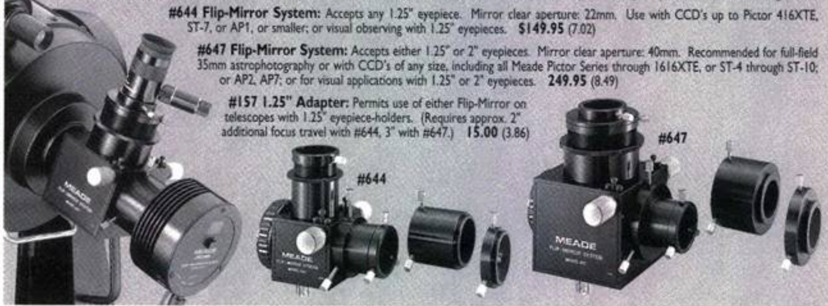
CCD-Photo-Visual Flip-Mirror Systems

Use with _any_ brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XTE, ST-7, or AP1, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XTE, or ST-4 through ST-10; or AP2, AP7; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)



Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5° at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

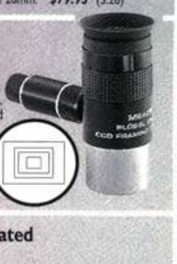
2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of longer focal-length Barlows. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

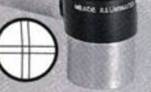
Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm. **$79.95** (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular



Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models; ST-4 through ST-8; AP1, AP2; and others. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above)*. Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25". **$129.95** (4.54)



MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included. $99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue — each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

ETX® Hard Carrying Cases

For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, optional eyepieces, erecting prism, table tripod, hand controller, etc. Includes steel latches & key.

#774 Case for ETX-90 models: **99.95** (8.58)
#776 Case for ETX-105 models: **99.95** (8.58)
#775 for ETX-125 models: **149.95** (13.38)

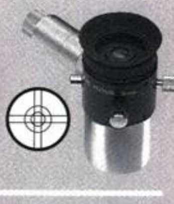
Electric Focusers for ETX®

Meade-engineered for smooth, rapid focusing with ETX-90, -105, or -125. Four-speed operation from coarse to microfine. Standard-equipment hand controller accepts one 9v. (user-supplied) battery and focuses all ETX telescopes. Or focus through the telescope's Electronic Controller (EC) or through Autostar.

#1244 Electric Focuser for all ETX-90 and ETX-105 models: **$119.95** (6.85)

#1247 Electric Focuser for ETX-125 models: **$119.95** (6.85)

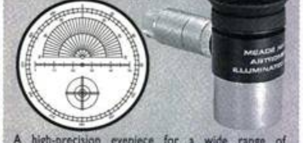
World's Most Advanced Illuminated Reticle Eyepiece



Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25". **$149.95** (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. **$129.95** (5.26)

MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25". **$119.95** (4.26)

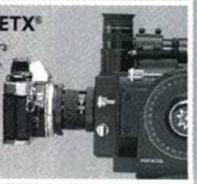
Series 4000™ 8mm – 24mm Zoom Eyepiece

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25". **$219.95** (6.38)

#825 8 x 25mm Right-Angle Viewfinder for ETX-90

Replaces standard-equipment finder on ETX-90, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing. **$49.95** (4.26)

#64 T-Adapter for ETX®



Rigidly couples any 35mm camera with removable lens to ETX-90, ETX-105, or ETX-125 for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera. **$34.95** (3.86)

#932 45° Erecting Prism for ETX®

For terrestrial observing with any ETX-90, ETX-105, or ETX-125 model. Yields correctly oriented image and convenient 45° observing angle. Threads to ETX rear cell. Accepts any 1.25" eyepieces. Coated roof prism optics. **$49.95** (3.86)

Dew Shields for ETX®

Threads into the front lens-cell and effectively inhibits the formation of dew on the lens surface.

#670 for ETX-60/70	19.95
#673 for ETX-90	24.95
#675 for ETX-105	27.95
#678 for ETX-125	29.95

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

ANACORTES TELESCOPE, Anacortes, WA.
Orders & Information: 800-850-2001.

RIVERS CAMERA, Dover, NH.
Orders & Information: 800-245-7963.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 847-367-4600.

WOODLAND HILLS CAMERA & TELESCOPE, Woodland Hills, CA. Orders: 888-427-8766; Info.: 818-347-2270.

EFSTONSCIENCE, Toronto, Ontario, Canada
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario, Canada
Orders & Information: 416-783-4140.

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MEADE LXD55

High-resolution 5" and 6" achromatic refractors and 8" Schmidt-Cassegrain on the Autostar®-controlled LXD55 equatorial mounting.

Meade LXD55-Series Achromatic Refractors and Schmidt-Cassegrain. Supplied complete with Autostar control system, as shown.

(top to bottom)
6" Model AR-6;
5" Model AR-5;
8" Model SC-8.

Use the pushbutton Autostar controller to observe "an object a minute," as you fast-slew across the sky at 4.5°/second, unerringly locating over 30,000 objects in Autostar's database, including the complete Messier, Caldwell, Index Catalog, and NGC listings. All at your fingertips, and in high resolution, with a Meade LXD55 achromatic refractor or Schmidt-Cassegrain.

Complete with #497 Autostar Controller:

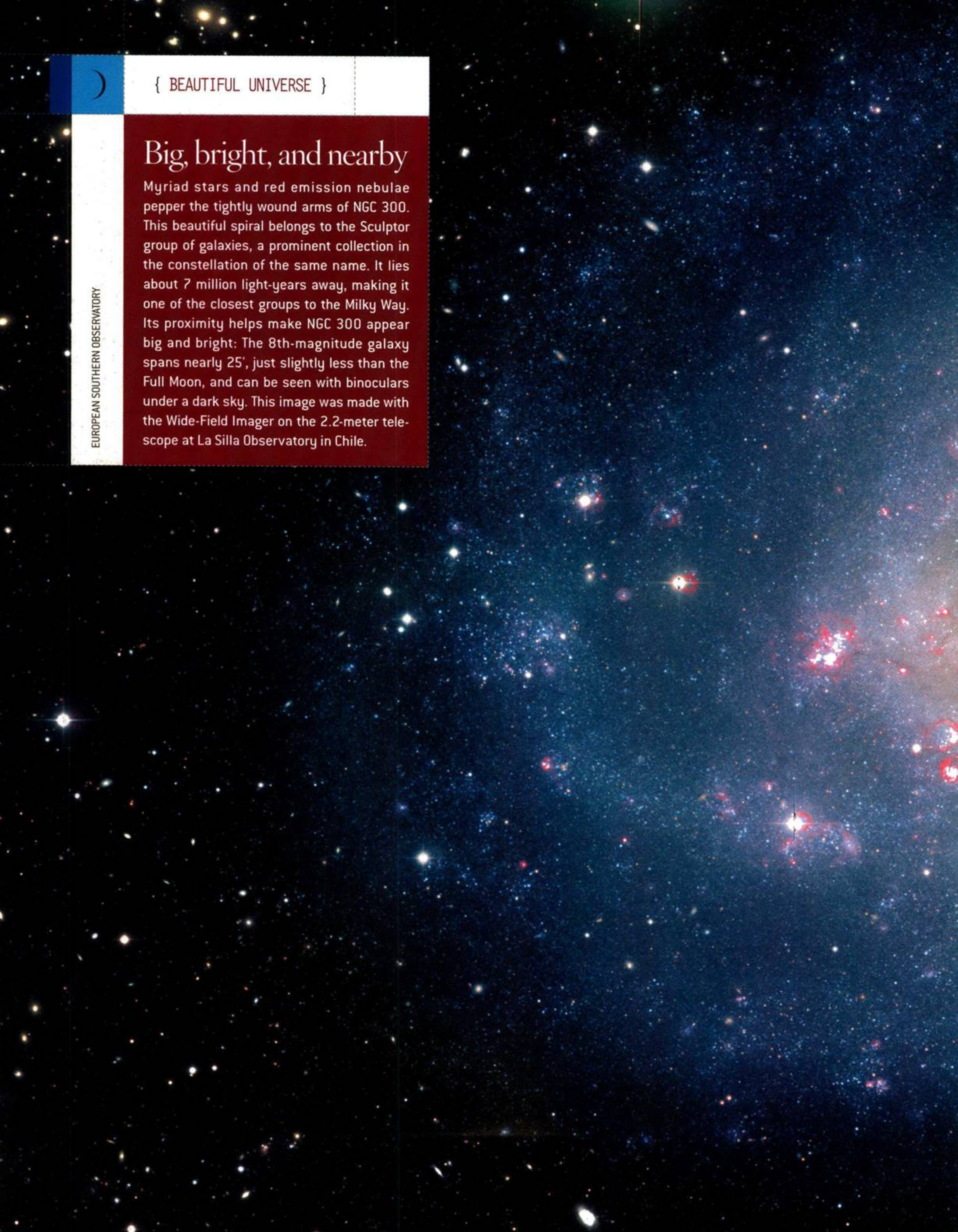
Model AR-5: 5" f/9 Achromatic Refractor	**$695**
Model AR-6: 6" f/8 Achromatic Refractor	**895**
Model SC-8: 8" f/10 Schmidt-Cassegrain	**1195**

Ultra-High Transmission Coatings (UHTC) Group for Model SC-8 – $175.

Packing & shipping charges in the 48 states: 8" – $85; 5" – $85; 6" – $95.

MEADE
LXD55 EMC
MEADE
LXD55 EMC
MEADE
LXD55
SUPER PLÖSSL 40mm

Buy a $650 Super Plössl eyepiece set for your LXD55 telescope for only $99! ***See ad on page 8 for details!***



Big, bright, and nearby

Myriad stars and red emission nebulae pepper the tightly wound arms of NGC 300. This beautiful spiral belongs to the Sculptor group of galaxies, a prominent collection in the constellation of the same name. It lies about 7 million light-years away, making it one of the closest groups to the Milky Way. Its proximity helps make NGC 300 appear big and bright: The 8th-magnitude galaxy spans nearly 25', just slightly less than the Full Moon, and can be seen with binoculars under a dark sky. This image was made with the Wide-Field Imager on the 2.2-meter telescope at La Silla Observatory in Chile.

EUROPEAN SOUTHERN OBSERVATORY

Anyone can sell you a telescope.

Last year was the biggest year in our history. We shipped 19,336 orders from ***astronomics***. And our business was up another 17% in the first four months of this year. *Why?* Because we took the time to make sure each customer was getting the right telescope or accessory – one that did what he or she wanted, at a price they could afford.

We take the time to listen to what you need. We answer your questions truthfully and take the time to explain your options. And we have the experience – a staff total of 160 years of experience using and selling telescopes – to make sure you have the scope and accessories that are right for you.

Unlike camera stores and shopping mall gift shops, telescopes are our specialty at ***astronomics***, not just a sideline. We're a family-owned full-line telescope dealer – not a few toy telescopes stuck off in the corner of some no-help department store, toy store, or gift shop as an afterthought. And, unlike department store clerks, we don't work on commission, so we won't try to sell you more than you need just to pad our paychecks.

We've been helping people choose the right telescope since 1979. We have the experience to help you pick the scope that fits your needs . . . and your budget . . . from the hundreds of Celestron, Discovery, Meade, Questar, Stellarvue, Takahashi, TeleVue, TMB, and Vixen scopes we stock. And with our large inventory, we can usually ship you the right scope right away.

astronomics. No hard sell. No guesswork. Just honest advice, the time to make sure you get the right telescope and accessories, and a good price. Call us toll free at (800) 422-7876 and find out for yourself.

The Meade LXD55 scopes . . . *not your father's same old telescope.*

Meade 5" AR-5 go-to refractor

$695

$839

Meade 8" f/4 go-to Schmidt-Newtonian

Why pay for an ordinary equatorial mount refractor or reflector just like the one your father or grandfather grew up with as a child? Not when you can get a modern and fully computerized go-to Meade LXD55 scope for the same price? The computerized go-to capability of the LXD55 series is the most significant advance in an affordable German equatorial mount since the mount was invented in the early 1800s!

You won't spend all your time hunting for faint deep space objects with a 5" or 6" LXD55 achromatic refractor or a fast focal ratio Schmidt-Newtonian 6" to 10" reflector (either with standard or optional UHTC optics). A few touches on the supplied Autostar computer hand control sends your scope speeding to any of the more than 30,000 stars and objects in its memory, centers the object, and tracks it precisely as you observe. You'll spend more of your time looking *at* deep space objects and planets and less time looking *for* them with an LXD55.

Each comes with an adjustable height tripod, dual-axis DC motor drives, an accessory tray, finderscope, eyepiece, and Autostar computer. Order now and get your German equatorial observing out of the dark ages.

Why wait? We'll ship your Meade LX90 from stock.

Meade 8" LX90

$1495

The 8" **Meade LX90** lets you enjoy go-to astronomy for not a lot of money. The LX90 is only $1495 with standard optical coatings. Ultra High Transmission Coatings (UHTC) provide images up to 20% brighter for only $175 more. Both versions include tripod, 8x50mm finder, Autostar computer hand control with a 30,223 star and object data base, and a 26mm Plössl eyepiece.

We usually have both LX90s in stock, so you can probably get *your* scope with little or no delay. If Meade is shipping the LX90 *(or any Meade telescope)* for a dealer to keep in stock, chances are good we *have* it in stock.

Meade prices are about the same anywhere you call. So why order a Meade product from a non-stocking dealer who charges your credit card, then makes you wait and wait until he finally gets around to ordering what you want? Not when you can usually get the Meade telescope or accessory that you want from stock . . . right now . . . at the right price . . . right here at ***astronomics***.

The new Celestron NexStar 8i modular 8" GPS-ready SCT starts at only $1199!

NexStar 8i

$1199

shown with optional tripod and computer

The **Celestron NexStar 8i** costs less than other comparably-equipped 8" go-to scopes. Starting at only $1199 for a dual-axis drive tabletop scope, you can add the options you and your budget feel comfortable with. An *iCOMP* go-to computer hand control with a 40,000 deep space object memory is $149. A tripod is $149. A heavy duty tripod (the same as on the NexStar 11) is $299. If you want GPS (an unavailable option with other scopes), you can add it for only $199. No matter how you outfit your NexStar 8i, it's enough scope to keep you observing for the rest of your life, at a price that leaves other scopes behind.

CELESTRON

Takahashi – *premium optics on sale right now!*

FSQ-106N, $3475.
EM-2S mount, $2229.

While many people swear *at* the one to three year delivery schedule quoted by some premium refractor makers, most experienced astronomers swear *by* the unsurpassed optics and fast delivery of the Takahashi *apochromatic* refractors we keep in stock.

The 3.1" **FS-78** fluorite apo doublet optical tube is on sale for **only $1195!** It's regularly priced at $1379. You save $184!

Takahashi's unique ***Sky 90 II*** 90mm f/5.6 is on sale for **only $1849!** It's regularly $2279. You save $430! With its self-storing dew shield retracted, this remarkable fluorite apo is less than 14" long! *Sky & Telescope* called it "an ideal travelscope for mobile observers, providing maximum performance at minimum size."

The best-selling 4" **FS-102** fluorite apo doublet optical tube is on sale for **only $1895**! It's regularly $2349. You save over $450!

And the big 5" **FS-128** fluorite apo doublet optical tube is sale-priced at **only $4495**! It's regularly $5249. You save over $750!

We also stock the 22" long Takahashi **FSQ-106N** 4-element f/5 4" *dual fluorite* apo refractor OTA, shown on an optional mount to the left. At $3475, this OTA is an affordable astrograph.

If you want premium optics, and you want them without a lo-o-o-o-ng wait, the scope you want is a Takahashi from ***astronomics***.

Sirius filters . . . for serious astronomy.

Sirius minus violet filters reduce spurious color so that achromatic refractors can approach costly apo scopes in performance. Sirius contrast enhancement filters improve nebula and galaxy views without degrading stellar brightness and color. If you're serious about seeing realistic planetary and deep space images, see the Sirius filters on our website.

Need a Vixen? It's in stock.

$2200

Vixen

Vixen GP ED102S 4" f/9 ED apo (with optional drive)

For years, Vixen scopes and accessories from Japan have been European best-sellers. Now, Vixen quality is available in the United States – imported by TeleVue, a company with a sterling reputation for quality of its own.

Whether it's a fluorite or ED scope, a Great Polaris mount, or a lanthanum long eye relief eyepiece, if it's from Vixen, chances are good we have it in stock. Our website at **www.astronomics.com** has full details and prices on the models we have in stock.

A whole lot less shaking going on!

Canon

Sky & Telescope said hand-holding Canon image-stabilized binoculars was "a quantum leap in binocular observing." Canon's stabilized images are rock-solid, not jittery and blurred, no matter how unsteady your hands. You'll simply see more deep sky detail than you can with conventional binos. There are two 50mm models that are excellent for astronomy. Full details are at **www.astronomics.com**.

A new TeleVue telescope, new eyepieces, filters, and more.

$5975

Mount and eyepiece optional

The newest TeleVue telescope is the limited edition **NP-127**, shown to the right on an optional Vixen Great Polaris DX wood tripod mount. This 4-element 5" aperture f/5.2 apo refractor is priced at $5975. If that's too rich for your blood, here are a few of the other TeleVue refractor optical tubes that we keep in stock.

NP-101, 4" f/5.4 apo	**$3595⁰⁰**
TV-102, 4" f/8.6 apo	**2635⁰⁰**
Renaissance 102, 4" f/8.6 brass apo	**2935⁰⁰**
TV-85, 3.35" f/7 apo	**2080⁰⁰**
TV-76, 3" f/6.3 apo	**1675⁰⁰**
Pronto, 2.7" f/6.8 semi-apo	**1120⁰⁰**
Ranger, 2.7" f/6.8 semi-apo	**695⁰⁰**

Three of the newest TeleVue eyepieces are the 2.5mm, 3.5mm, and 11mm 1.25" Type 6 Naglers at $280 each. There's also a new 2" 41mm Panoptic at $495.

There's a new $840 BinoVue without image amplifier that's designed for use with long back focus Schmidt and Maksutov Cassegrains.

And TeleVue now has premium 1.25" Bandmate Oxygen III and UHC light pollution filters at $125 each (2" versions are $215).

> For what it is worth, I have found that dealing with your people has been a very pleasant experience. I have found them to be very helpful when I didn't understand something about my telescope. They always have been polite and courteous. I realize that my orders are not for very much money, however, I do recommend your business to other people in and outside the Buffalo Astronomical Association.
>
> **Customer Quote of the Month #137**

More than 1,000,000 people a year visit our website for reliable info, helpful features, and secure on-line shopping.

www.astronomics.com

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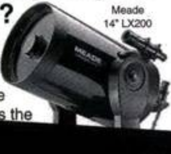
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Celestron NexStar 11 GPS

a $2999 value, to be given away *free!*

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The review said the scope had "brains and good looks. The NexStar 11 GPS puts Celestron's time-tested 11-inch f/10 Schmidt-Cassegrain optics in a sleek new package that includes some of the most advanced electronics ever offered in a mass-produced telescope . . . Celestron is the first to take Go To scopes to the next step in their evolution, and it's a nice step indeed."

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The **Celestron NexStar 11 GPS** is a $2999 value telescope – but it can be yours with no purchase required if you win our free drawing!

Meade and Astronomics are giving away a **Meade 12" LX200GPS** telescope – with all the features you've dreamed about since you started astronomy. It even includes normally optional UHTC (Ultra High Transmission Coatings) that give you up to 20% higher light transmission so you can see 20% more of Mars and the Universe.

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Discovery 8" f/8 Marscope Dobsonian

a $999 value, to be given away *free!*

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also deliver impressive deep space views. It's complete with a 7mm TeleVue Nagler eyepiece, 1.25" reverse Crayford focuser, a tube balance system, tube handle, and diffraction-limited Pyrex optics.

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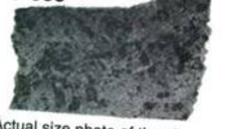
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Compact galaxy trios

"The turbulent world of compact galaxy groups" by Marcia Bartusiak (April 2003) struck me as exciting. I started using the *Hickson Atlas* as an observing guide when it was published in 1994 and soon observed more than 90 of the Hickson groups. Because galaxy trios were not included in the *Hickson Atlas*, I began a list, including those that I found during my observing. I compiled my atlas comprising SkyView Digital Sky Survey (DSS) images of the 137 I found most intriguing. My atlas was published by the Webb Society in their *Quarterly Journal*, #122, Autumn 2000. A southern supplement to the atlas comprising an additional 54 groups from 32° south to 90° south was published in #128, 2002. Both are available from the Webb Society. I will be glad to provide my entire catalog of 607 compact galaxy trios to observers who email their request to me at mwalimumiles@yahoo.com with "trio catalog" in the subject line.
— MILES PAUL, VICTORIA, BRITISH COLUMBIA, CANADA

STEPHAN'S QUINTET (HCG 92) contains five galaxies tightly corralled within the constellation Pegasus. N. A. SHARP/NOAO/AURA/NSF

Double star astronomy

The *Double Star Observer*, a publication devoted to visual double star astronomy, has grown over the last 10 years from an eight-page newsletter to a thirty-page scientific journal. So far, we have contributed more than 1,500 double star measurements to the *Washington Double Star Catalog*, the world's largest double star database.

The second edition of my book, the *Double Star Observer Handbook*, will be the largest and most up-to-date book available on the subject of visual double star astronomy. I hope it inspires other amateurs to take a serious interest in observing double stars.
— RONALD C. TANGUAY, EDITOR AND PUBLISHER, *DOUBLE STAR OBSERVER*, SAUGUS, MASSACHUSETTS

Naming asteroids

We, the founders of MPC Observatory 643, are a not-for-profit minor planet research team. With 50 asteroid discoveries to our credit, we are currently at a loss for names. We have initiated an honorary naming campaign for some of these objects from our own website at www.mpc643.org. Please feel free to view the details of our campaign at the website. **— MINOR WHITE AND MYKE COLLINS,** MPC OBSERVATORY, ORANGE COUNTY, CALIFORNIA

Glenn Chaple's equipment review

I read with great interest Glenn Chaple's "SkyQuest: Easy exploring" (May 2003). I enjoyed the article, as our club owns several of the scopes evaluated in the article. However, the article states that because the XT6 and XT8 have identical focal lengths the views are similar. Actually, the XT6 is a 6-inch f/8, and the XT8 is an 8-inch f/5.9. Therefore, these telescopes provide identical magnifications when using the same eyepiece, making the views "comparable."
— ED CONLEY, LAPEER, MICHIGAN

I enjoyed Mr. Chaple's article about the XT6 and XT8s, but an experience of mine prompts me to offer a correction to the author's statement that Coulter Optical Company is no longer in business.

I have an early 1980s vintage Odyssey Compact. This winter I decided to replace the secondary mirror and install a new spider vane. While browsing on-line, I discovered that Murnaghan Instruments Corp., which purchased the ailing Coulter Optical Company, offers mirrors, as well as vanes and focusers, of the same type once offered by Coulter. While production of the scopes has ceased, at least temporarily, new replacement components are still offered, along with advice about installation. When I called Murnaghan Instruments, on a national holiday, with questions about the installation of my new secondary mirror and vane, I was connected with Bill Murnaghan, who, while bouncing his grandchild on his knee, gladly answered my questions. Customer service like this deserves recognition.
— ALBERT ARMSTRONG, BRIER, WASHINGTON

Correction

In "The Paramount GT-1100 ME" (April 2003), metric conversions for telescopic apertures were miscalculated.
— ASTRONOMY EDITORS

We welcome your comments. Send letters to Astronomy Letters, P.O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.

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BY BOB BERMAN

Handling Mars

On August 27, a day before its opposition, Mars will be nearer to Earth than anytime in the past . . . what? Three thousand years? Ten thousand? Eighty? Different figures are thrown around. It's hard to trust computer simulations beyond a few millennia, but no matter how it's sliced, this is an historic occasion.

Mars approached just a hair less close and appeared only 1/100 of an arcsecond smaller back on August 22, 1924. According to some sources, it'll venture even nearer on August 28, 2287. See what's happening? Earth's and Mars's oval orbits are rotating as well as ever-so-slightly changing shape. The narrowest gap between the two worlds slowly shrinks with time.

Normally a target that challenges observers to get excited, Mars is now truly worthwhile. At 25.11 arcseconds, its disk grows to more than half of Jupiter's — but stays noticeably big only until the end of September. This oh-so-brief window of opportunity makes each night precious.

Transparency is unimportant. In fact, you don't want a sky bursting with thousands of stars and a prominent Milky Way. Mars is more than bright enough to bulldoze its way through haze; instead, you need an image that doesn't blur and wiggle. The most important tips follow.

Appraise the night

A star-studded sky is usually bad because clarity goes hand in hand with low humidity. Dry air chills rapidly after nightfall, often creating disparate air masses that refract light into carnivals of blurry horror. High humidity, by contrast, helps to steady atmospheric temperatures. Air doesn't cool below its dew point: A humid day with a dew point of 68° won't fall below 68° F that night. Damp air reluctantly loses heat and when it does, fog may eventually form. But before that happens, the sky will be hazy with only the brighter stars visible. Oddly enough, that's the ideal night to view Mars.

Where to set up the scope?

Clear viewing of planetary features demands homogeneous air. It's not merely enough to avoid lunatic behavior like poking the scope out a window. Get away from the residual daytime heat of houses, paved driveways, and stone-faced patios. Heaven has sent us a perfect surface for setting up a telescope, one that barely radiates: grass. The lawns of a mental institution or cemetery blow away a mall parking lot. Nothing wrong with watching the strange planet from a strange location.

No business like show business

Don't neglect the showbiz aspect if you're sharing Mars with friends and family. Count on this rare Mars visit to make headlines. People will enthusiastically accept your offer to see Mars in person. Problem: The pictures on the news won't look remotely like the tiny orange blob you can show them. TV will feature exquisite Hubble images resembling your eyepiece view the way Mary Kate and Ashley resemble Osama Bin Laden. Result: Your telescope will seem defective.

Be careful not to make things worse. What some of us forget is that we long-ago made peace with the fact that serious planetary observing requires monastic-level patience for those moments when the image isn't dancing. We're also accustomed to the planet's disk being small compared with the field of view. We don't even notice it. But your friends, parents, and especially that cute neighbor who has decided to come take a look — they don't know what to expect.

Expectation vs. reality

A newcomer's experience is always a function of expectation versus reality. Mars is tough because expectations are very high. They've seen those gorgeous close-up shots. You simply can't compete. How to overcome that handicap?

First, don't make them visualize something better than what they'll experience through your eyepiece. That's a drive down Disappointment Boulevard. Instead, downplay Mars before they take their look. Tell them how experienced observers wait hours to catch steady moments. Tell them Mars has little, blurry surface features and a polar cap, but add: "You're not likely to see anything on the planet unless you're lucky." Then watch what happens.

When they do see something, they'll be excited. They'll feel successful. That's when narration can be added for drama: "You're seeing detail on the surface of another world! With other planets like Jupiter, we only glimpse the tops of clouds." This makes the Red Planet even more real.

Have one other tantalizing item on hand to serve them for dessert. If the sky is dark, with a thin or absent Moon, choose the Hercules Cluster if your scope is 8-inches or larger. Choose M57 if it's a smaller instrument. Novices have never heard of these things so expectations are zero, guaranteeing surprise and delight. If the sky is brightly polluted, focus on the Moon during the first half of August, in any phase except full. Then the last thing they'll remember will be glorious. They'll leave with a positive feeling about astronomy, your telescope, and you.

That's the time to seize the moment and sell them life insurance.

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BY GLENN CHAPLE

Mars revealed

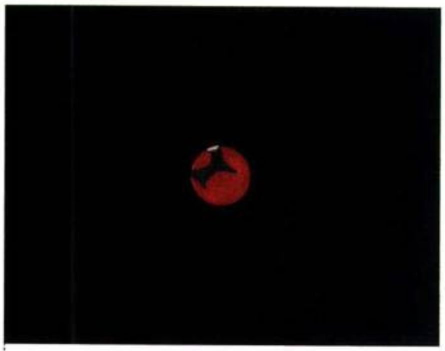
Last month, this column made you see double. This time around, you'll be seeing red. If you were with me last month, you'll know that the vision game I'm about to play is astronomical in nature. The red you'll be seeing is the planet Mars.

Of all the planets in the night sky, Mars is arguably the most fascinating. Even ancient skywatchers marveled at this "wandering star." For months on end, Mars would shine meekly like an ordinary 2nd-magnitude star. Every two-and-a-half years, however, as Mars approached opposition (a location in the sky opposite the Sun), it would brighten — sometimes by 4 full magnitudes. As Mars brightened, its ruddy hue became more distinct. Compared to the other planets, which shone with white or off-white hues, Mars seemed blood red — perhaps a harbinger of death and destruction. Indeed, Mars was the Roman god of war.

The advent of the telescope did little to quell the fear of Mars. Under telescopic scrutiny, Mars seemed eerily earthlike. Could the gray-green areas in an otherwise reddish disk be vast, plant-filled oases sprouting forth from a global desert? And was it possible those remarkable straight lines some astronomers perceived were canals created by an advanced civilization?

In 1898, *War of the Worlds*, a science fiction novel by British author H. G. Wells, brought these fears to life. It described an invasion of Earth by martians envious of our planet's abundant water supply. A radio dramatization of this novel in 1938 created a minor panic in the United States. Both the radio program, and later the movie, fueled the debate among astronomers as to whether martians and their canals actually existed.

Space probes to Mars have all but erased the notion that Mars is inhabited. Gone are the oases, canals, and cities, replaced by towering volcanoes and enormous canyons. But the idea of Mars as the abode of hostile aliens lives on.



THIS MONTH'S MARS OPPOSITION will appear through smaller telescopes much like Glenn Chaple's sketch of the Red Planet's 1971 opposition. Chaple observed Mars through a 60mm refractor at 120x. GLENN CHAPLE

With or without martians, the allure of the Red Planet remains. With another opposition upon us, it's time to join the legions of astronomers worldwide for another Mars watch. Don't assume that you'll be left out if you don't own a telescope. Mars will be an impressive sight even when viewed with the unaided eye.

Observers who want to see Mars "up close and personal" should do so with large, high-quality telescopes and magnifications as high as atmospheric conditions allow (often in excess of 300x). But we small-scope users won't be left out. Back in 1971, during an opposition similar to the current one, a small scope surprised me by clearly revealing Mars's true yellowish-orange hue as well as some of the planet's surface features.

Be forewarned that Mars is a notoriously difficult telescopic target. At best, the planet's disk will be about 25 arcseconds across — the angular size of a typical lunar crater. So high magnification is important. The maximum useful power for any telescope is about 50x per inch of aperture (the diameter of the scope's objective lens or mirror). For a standard 60mm (2.4-inch) refractor, that's 120x.

Mars-watchers learn the value of patience. Peering into the eyepiece, turbulence in our atmosphere distorts the image. For minutes, Mars boils and seethes. Suddenly, everything settles down and, for a few fleeting moments, Mars's image is crystal clear. The higher in the sky Mars is, the less its image will be disturbed by the atmosphere. During this month's opposition, Mars is low in the southern sky (about where the Sun is during winter), so you'll need to wait until Mars is as high in the sky as it can get (which means around midnight) for the best view.

As if our own blanket of air doesn't pose enough problems, Mars's atmosphere can make viewing even worse. As a desert planet, Mars is frequently beset by concealing dust storms. One can completely cover the planet within a few days, frustrating our attempts to view the surface. Hopefully, the dust storm season won't begin until September or early October, so check out Mars now.

If you want to know more about Mars, read the article by Michael E. Bakich, beginning on page 80 of this issue. It includes facts about the Red Planet, plus more observing tips.

Answer to July's trivia question: The star located between Mizar and Alcor is known as Sidus Ludoviciana (Ludwig's Star). An astronomer who saw this star in 1723 named it in honor of his monarch, Landgrave Ludwig of Hessen-Darmstadt.

NEXT MONTH: *We go for a cruise, Milky Way style.* Clear Skies! ■

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In ***Understanding the Universe: An Introduction to Astronomy,***
a Teaching Company video course taught by Professor Alex Filippenko

> ***"The most incomprehensible thing about the universe is that it is comprehensible."***
>
> —Albert Einstein

This course begins and ends in wonder and awe. Whether you are a seasoned student of astronomy or a newcomer to its marvels, this course can give you fresh insight into the astounding comprehensibility of the universe, and the mind-boggling mysteries that still remain.

Why Now?

This course—taught at this time, by this professor—is scientific adventure at its best.

Digital Vision, Astronomy and Space.

We are living in a "golden age" of astronomical research and discovery. Ten years ago, black holes and planets around other stars had not yet been observed. Now, they are discovered every month. Ten years ago, the universe was thought to be a very different size and age than we now think it is. Ten years ago, scientists could not find the 90% of the universe that was "missing" if the Big Bang theory was true—and they still haven't found it.

These lectures will increase your understanding at every turn. You'll range over the history of astronomy from the ingenious calculations of the ancient Greeks to the latest theoretical speculations and technological breakthroughs, including the vast change in our understanding made possible by a handful of special telescopes.

You'll explore, in depth, everything from our own solar system to the farthest detectable galaxies, and learn about the actual scientific evidence surrounding widely discussed—and frequently misunderstood—topics like the Big Bang theory and the prospects of extraterrestrial intelligence and interstellar travel.

A "Superstar" Astronomy Professor

The Teaching Company could find no one better suited to lead you on this voyage through the cosmos than Professor Filippenko of the University of California at Berkeley, who has done award-winning research on topics such as supernovae, black holes, active galaxies, and observational cosmology. In 1998, *Science* magazine credited Professor Filippenko and his international team of astronomers with the "Science Breakthrough of 1998." Filippenko and his colleagues received this recognition for research on supernovae which seems to show that the universe is expanding at an accelerating rate.

Professor Filippenko has also distinguished himself by the excellence of his teaching: he has won both of his university's top two teaching awards, and in 1995 was voted "Best Professor on Campus" by students. Professor Alex Filippenko will make the universe comprehensible for you.

This course is illustrated with photos from the Hubble space telescope and other visual images. Dr. Filippenko designed the visual aids in the course himself in the form of graphics that use words and diagrams to make basic astronomical laws and concepts clear—without the need for a background in physics or mathematics.

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Offer Good Through: August 20, 2003

BY WILLIAM SCHOMAKER

Peter Hauschildt

As one of modern astronomy's more reluctant role models, Peter Hauschildt often finds himself doing a virtual reality check. Not only has he hoodwinked institutions into giving him unfettered access to multi-million dollar supercomputer systems to blow things up — he also gets paid for it.

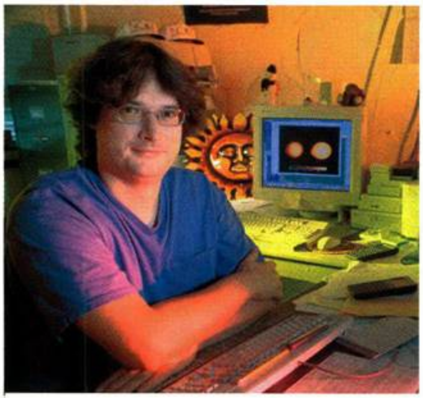
While some consider computational astrophysics little more than "Nintendo astronomy," Hauschildt is one of a successful band of coders who have quieted critics with real results. His work with the monolithic PHOENIX stellar atmosphere code — which can recreate just about any type of celestial spectrum, from extrasolar planets to supernovae — forms a theoretical cornerstone for the behavior of Type Ia supernovae and the accelerated expansion of the universe.

If you visit the Hamburg Observatory, look for Hauschildt shuffling about in his Birkenstocks and going by his email alias, Yeti. But don't let him near the telescope. And thank goodness he didn't develop his penchant for blowing things up while he was transporting nuclear artillery for the German army at the peak of the Cold War.

How did growing up in a German harbor town on the North Sea shape your courtship with physics and computation?

Husum is small, about 20,000 people, and we lived some 150 feet from the harbor itself. I went to a 450-year-old high school there, where almost all of the teachers were really good.

Pretty early, I gave up on a career in chemistry — too dangerous . . . too many fumes and nasty chemicals. That's when I decided to try astronomy because it has something of everything — physics, chemistry, math, computer science, and so on. I wanted to do computer modeling even then, although the only computer the school had was an ancient HP that read magnetic cards and ran a Moon landing simulator that I hacked together in machine code. But it refused to run my stellar structure code, and that's when I realized that I prefer really big computers.



PETER HAUSCHILDT observes the sky with the unlikeliest of devices: computers, calculators, and codes. NANCY EVELYN

Does PHOENIX's ability to precisely replicate behavior of diverse objects imply that knowledge of the physical laws that govern them is near complete?

Nope, fortunately not. Otherwise I'd have to search for a new field to work in!

To be honest, I'm amazed that the primitive models we make today give such good results. Lots of problems still need to be addressed with even the best models to make them more "realistic." Developing more complete spectral line data (in particular for molecules) and more realistic physical conditions, including 2-D and 3-D geometry and time-dependent behavior, will keep theorists busy for generations.

To what do you owe the versatility and robustness of PHOENIX?

At 500,000 lines of code and growing, PHOENIX was designed to be as flexible and general as possible. Part of the fun of this type of work is to try new ideas and make the code do things that I didn't think of before. Quite often, this leads to useful "synergy effects." For example, some numerical methods developed for nova and supernova modeling turned out to be even more effective applied to M and L dwarfs — cool, solar-type stars.

Also, the different modules and pieces of the code are tested and verified often and with very different parameters — leading to increased robustness of the code.

But you don't like to think of your research subjects as individual objects. Why not?

There are too many of them. If you look at just a few individual objects, it's easy to lose sight of the bigger picture, which interests me most.

With a self-confessed aversion to stargazing and telescopes, how do you explain your rise through the ranks of astronomy?

Hey, I like telescopes and have the utmost respect for observational astronomers. It's amazing how they collect great data for extremely dim objects. I'm just not very good with large mechanical devices. They're out to get me!

Regarding my "rise through the ranks," it must be (a) I'm full of gas, or (b) lighter than air. And (b) is certainly not the case, so it must be (a). Frankly, I don't care about any of that as long as I can continue to do what I like to do. ■

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15mm	$139.00	19mm	$189.00
19mm	$149.00	34mm	$239.00
23mm	$179.00	40mm	$289.00
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- **5-element hybrid optical design**
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- Blackened lens edges

5mm	$ 79.00	18mm	$ 79.00
7.5mm	$ 79.00	30mm	$ 99.00
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- Made of high quality, flat polished optical glass
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2":		1-1/4":	
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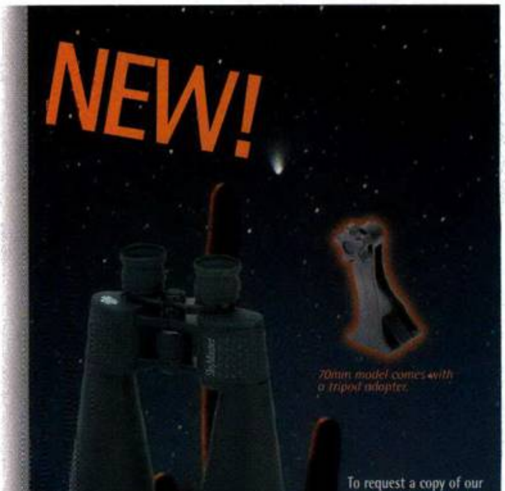

70mm model comes with a tripod adapter.

To request a copy of our new 2003 BINOCULAR CATALOG or our new 2003 PRODUCT GUIDE, please contact us at: (310) 328-9560.

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Celestron's new SkyMaster Series of large aperture **porro prism** binoculars offer phenomenal performance for astronomical viewing or low light conditions. They are also a great choice for terrestrial use, especially over long distances. All models feature high quality **BAK-4 prisms** and have **multi-coatings** for enhanced contrast. The 80mm and 100mm models are **waterproof** and feature an integral **super rigid photo tripod adapter for structural reinforcement** of the main body and maximum stability and secure optical alignment. The 15x70 model is **lightweight** and features a **tripod adapter.**

80mm and 100mm models come with a deluxe padded soft carrying case.

SPECIFICATIONS

Model	71009	71016	71017
Size	15 x 70	20 x 80	25 x 100
Prisms	BAK-4	BAK-4	BAK-4
Focus	Center	Individual	Individual
Coating	Multi-Coated	Multi-Coated	Multi-Coated
Weatherproof	Water Resistant	Waterproof	Waterproof
Angular Field of View (FOV°)	4.4	3.3	3
Linear FOV (ft @ 1000 yd.)	230	173	157
Exit Pupil (mm)	4.7	4	4
Eye Relief (mm)	18	15	15
Near Focus (ft)	43	51	80
Weight (oz.)	48	82	157

Object: Hale-Bopp Comet
Photographer: Dean Koenig

Model 71009
15x70
$89

Model 71017
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C10-NGT
C10-N
C9 1/4-SGT
C9 1/4-S
C8-SGT
C8-S
C8-NGT
C8-N
C6-RGT
C6-R
C6-N
C5-SGT
C5-S
C4-R

Advanced Series

To design the perfect telescope family for the beginner or advanced user, you have to think BIG.

The new Advanced Series family of **computerized GoTo** and non-computerized telescopes was designed to offer the novice or more advanced user a selection of models with the **features, quality** and **value** that serious amateurs can appreciate. These scopes come on **NEW heavy-duty German Equatorial mounts** with **NEW ultra-sturdy 2" stainless steel legs** and center brace/accessory tray for superior stability, rigidity and vibration dampening. The Advanced Series comes in a choice of refractor, reflector and Schmidt-Cassegrain models. The refractor models range from a 4" to an impressive 6" aperture. For even more light gathering power there are 6", 8" and a **NEW 10" Newtonian** reflector. There are also 5", 8" and 9 1/4" Schmidt-Cassegrain optical designs that feature Celestron's precision **matched** and **hand-figured** optical systems.

CG-5 Mount — Precision engineered for stability.

Our new German Equatorial mount has precision worm gears on both axes for extremely smooth tracking and slewing. The CG-5 uses large shaft and bearings and substantial base castings for additional stability. The key element that makes this system the most stable in its class is the **NEW heavy-duty tripod** with **larger** and **more substantial** legs that offer excellent damping characteristics for more stable views. The CG-5 also has a convenient latitude scale for easier alignment and an optional polar finder scope for the ultimate in precision alignments.

The Advanced GT Series telescopes include these high performance features:

- **GPS-compatible with optional CN16 GPS Accessory (#93963)**
- Proven NexStar® computer control technology
- RS-232 communication port on hand control to control the telescope via a personal computer
- Autoguider port for long exposure astrophotography
- **40,000+ object database** with 400 user-definable objects and expanded information on over 200 objects
- Custom database lists of all the most famous deep-sky objects by name and catalog number; the most beautiful double, triple and quadruple stars; variable star; solar systems; objects and asterisms
- Double line, 16 - character Liquid Crystal Display Hand Control with 19 fiber optic backlit LED buttons
- DC Servo motors with encoders on both axes
- *The CG-5 GT computerized mount* features Celestron's sleek integrated design.

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C10-NGT #11048 ▶ (shown)
$1,149 + $ 95 S&H
C10-N Non-Computerized #11047
$ 849 + $ 75 S&H

◀ **C9 1/4-SGT #11046** (shown)
$1,699 + $105 S&H
C9 1/4-S #11045 Non-Computerized
$1,399 + $85 S&H

GoTo convenience and GPS compatibility for precision accuracy.

We are proud to offer the GT versions of the Advanced Series on a computerized **GoTo** version of Celestron's sturdy CG-5 mount. Couple this solid mount with the included computerized control system to utilize many of the same functions and features, like the **NexStar computer control system** and an **Autoguider port** for long exposure deep sky astrophotography, as Celestron's most advanced GoTo telescopes. **GoTo models are also upgradeable to GPS** with the optional **CN16 GPS Accessory (#93963)** allowing your telescope to pinpoint your position on the earth, the date and time, and making the alignment process faster and easier than ever before! These GoTo versions of the Advanced Series also come loaded with new software features and **over 40,000 database objects**. Capable of holding over 35 lbs of payload and slewing at 4° per second, you will be able to instantly point to any of the celestial objects in the database.

Specifications — All Advanced Series Telescopes

	21016 C4-R	11071/11072 C5-S	31056 C6-N	21019/21020 C6-R	11025/11024 C8-S	31061/31062 C8-N	11045/11046 C9 1/4-S	11047/11048 C10-N
Optical Design	102mm (4.0") refractor	127mm(5") Schmidt-Cassegrain	150mm (6.0") reflector	150mm (6.0") refractor	203mm (8") Schmidt-Cassegrain	200mm (8.0") reflector	235mm (9.25") Schmidt-Cassegrain	254mm (10") reflector
Focal Length	1000mm f/10	1250mm f/10	750mm f/5	1200mm f/8	2032mm f/10	1000mm f/5	2350mm f/10	1200mm f/4.7
Finderscope	6x30	6x30	6x30	9x50	6x30	9x50	6x30	9x50
Mount	CG-4 Equatorial	CG-5 Equatorial	CG-4 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial
Eyepiece	1-1/4" – 20mm (50x)	1-1/4" – 25mm (50x)	1-1/4" – 20mm (38x)	1-1/4" – 20mm (60x)	1-1/4" – 25mm (81x)	1-1/4" – 20mm (50x)	1-1/4" – 25mm (94x)	1-1/4" – 20mm (60x)
Star Diagonal	1-1/4"	1-1/4"	n/a	1-1/4"	1-1/4"	n/a	1-1/4"	n/a
Accessory tray	yes	yes	yes	yes	yes	yes	yes	yes
Tripod	Aluminum	2" Stainless Steel	Aluminum	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel
CD ROM	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky L1

Additional Specifications — Computerized Models

Hand Control	Double line, 16 character Crystal Display; 19 fiber optic backlit LED buttons
Motor: Type	DC Servo motors with encoders, both axes
Max Slew Speed	4°/second
Software Precision	24bit, 0.08 arcsec calculation
Hand Control Ports	RS-232 communication port on hand control
Motor Ports	Aux Port, Autoguide Ports
Tracking Rates	Sidereal, Solar and Lunar
Tracking Modes	EQ North & EQ South
Alignment Procedures	AutoAlign, 2-Star Alignment, Quick Align
Database	40,000+ objects, 400 user defined programmable objects

C4-R #21016
$ 399 + $40 S&H

C5-SGT
[11072]

C5-SGT #11072 (shown)
$1,099 + $ 75 S&H
C5-S #11071
$ 849 + $65 S&H

C6-N #31056
$ 399 + $50 S&H

C8-SGT
[11026]

C8-SGT #11026 (shown)
$1,299 + $ 75 S&H
C8-S #11025
$ 999 + $85 S&H

C8-NGT
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C8-NGT #31062 (shown)
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Our new 2003 Product Guide is free and features descriptions and specifications for all of our telescopes and astronomy binoculars, plus valuable general and technical information for both the beginner and advanced user. To receive a copy, contact Celestron at (310) 328-9560.

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30th ANNIVERSARY

Join us in Celebrating 30 Exciting Years of "Exploring the Universe"

Grand Prize

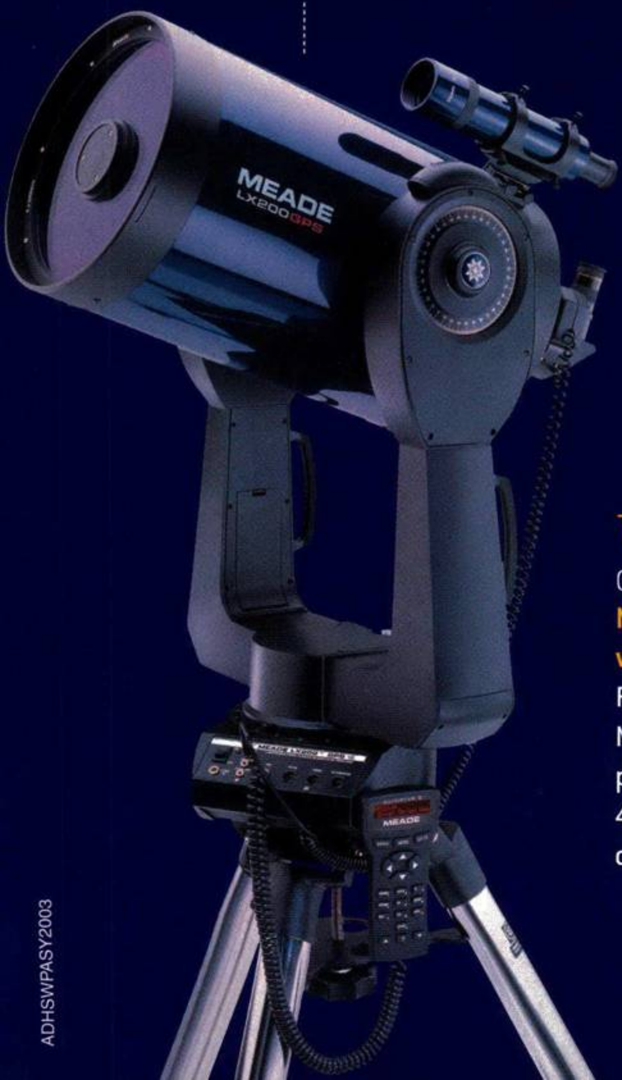
ONE AWARDED

Meade 10" LX200GPS Schmidt-Cassegrain–
Meade LX200GPS Schmidt-Cassegrains set the world standard for serious telescopes, with advanced technology, legendary diffraction-limited optical systems and uncanny 1-arcminute high-precision pointing in GO TO mode.

First Prize

ONE AWARDED

Meade 8" LX200GPS Schmidt-Cassegrain–
The telescope of a lifetime; includes Autostar II Computer Control System, zero image-shift micro-focuser, and much more.



Second Prize

ONE AWARDED

Meade 8" LX90 Schmidt-Cassegrain–
Diffraction-limited optics, Autostar GO TO capability, 30,000-object database, and 9-speed controls.

Third Prize

ONE AWARDED

Meade ETX-125EC with Autostar–
Renowned Meade 5" Maksutov-Cassegrain optics plus Autostar GO TO and 4-speed electric slow-motion controls on both axes.

Fourth Prize

ONE AWARDED

Meade ETX-90EC with Autostar–
Premium optics, precision GO TO, a 30,000-object database, 4-speed controls, and ultraportability.

MEADE

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First Prize — One Awarded

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Finder Scope storage vinyl cover included
ALL JMI CASES HAVE DIE CUT FOAM

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One Awarded

Telescope carrying case

Choose the perfect telescope carrying case from Jim's Mobile. (Case only)

Third Prize

One Awarded

SkyQuest XT8 Dobsonian

Great light-gathering power, point-and-view simplicity, superb optics, and more.

Fourth Prize

One Awarded

Astroscan Wide-Field Telescope

with Plossl eyepieces

Easy-to-use, telescope for beginners or experts seeking a portable second scope.

Fifth Prize

Five Awarded

Celestron Starter Kit

Includes night vision flashlight, Moon filter, 2x Barlow lens, car battery adapter, and foam-lined plastic carrying case.

STARTER KIT

Sixth Prize

One Awarded

Lunar Map Pro 1.5

Use your computer to explore and navigate the moon like an expert.

Eighth Prize

One Awarded

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THE BRILLIANT EARTH

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Four 24" x 36" prints include The Solar System, The Stars, The Planets, and The Galaxies.

Fill out and mail the attached card, or enter online at
www.astronomy.com
Entries must be postmarked by August 8, 2003!

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No Purchase Necessary. The official start date for the *Astronomy* 30th Anniversary Sweepstakes is April 28, 2003. Official entry forms are bound in the June, July and August 2003 issues of *Astronomy*. The *Astronomy* 30th Anniversary Sweepstakes is open to residents of the United States and Canada (except Quebec) only, 18 years of age or older. Employees (and their dependants and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies, and participating sponsors are not eligible to participate.

Sweepstakes Entry. To enter complete and mail the official entry form or a postcard with name, address, city, state or province, zip and telephone number on a postcard and sent it to: *Astronomy* 30th Anniversary Sweepstakes, P.O. Box 378, Waukesha, WI 53187-0378. Or enter online at www.astronomy.com by filling in the Online Entry form and hitting the SEND key. The Online Entry form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. One entry per household. The official ending date for the *Astronomy* 30th Anniversary Sweepstakes is August 8, 2003, and all entries must be transmitted or postmarked no later than that date.

Prizes and Odds of Winning. One drawing will be held on or about August 29 2003, for the following awards: One Grand Prize consisting of a Meade 10" LX200GPS telescope (retail value $2,995.00). One First Prize consisting of a Meade 8" LX200GPS telescope (retail value $2,495.00). One Second Prize consisting of a Meade 8" LX90 telescope (retail value $1,695.00). One Third Prize consisting of a Meade ETX-125EC with Autostar telescope (retail value $895.00). One Fourth Prize consisting of a Meade ETX-90EC with Autostar telescope (retail value $495.00). One BONUS drawing will also be held on or about August 29, 2003, for the following awards: One First Prize consisting of a Dark Sky Panel Observatory System (retail value $600.00). One Second Prize consisting of a Telescope Carrying Case (retail value $500.00). One Third Prize consisting of a SkyQuest XT8 Dobsonian (retail value $449.00). One Fourth Prize consisting of an Astroscan Wide-Field Telescope with 2 Plossl Eyepieces (retail value $209.00). Five Fifth Prizes consisting of a Celestron Starter Kit (includes a Night Vision Flashlight, Moon Filter, 2x Barlow Lens, Car Battery Adapter and plastic carrying case lined with foam) (retail value $115.95). One Sixth Prize consisting of the Lunar Map Pro 1.5 software (retail value $89.95). One Seventh Prize consisting of a Space Shot poster set (retail value $79.95). One Eighth Prize consisting of the Lunar Map Pro – Basic edition software (retail value $39.35). Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for *Astronomy* magazine is 160,226. Sweepstakes void in Quebec and void where prohibited.

Validation and Acceptance. Winners in the *Astronomy* 30th Anniversary Sweepstakes will be selected in a random drawing conducted by an independent judging organization whose decisions are final. Canadian prize awards subject to skill test requirement. By entering the sweepstakes, participants agree to be bound by these official rules and all decisions of the judging organization. Sweepstakes entries void if not legible, not completed in full, not obtained legitimately, or if forged, photocopied, mechanically reproduced, late or tampered with. The potential winners must sign and return an Affidavit of Eligibility, publicity release and Release of Liability within fourteen (14) days of notification. In the event of noncompliance, alternate winners will be randomly drawn. No responsibility is assumed for lost, stolen, misdirected or late entries or notifications. All sweepstakes entries become the property of the sponsor and will not be returned.

Winner's List. For a list of winners, send a stamped, self-addressed envelope to: *Astronomy* 30th Anniversary Sweepstakes Winners List, P.O. Box 1612, Waukesha, WI 53187-1612. Residents of FL, VT and WA may omit stamp. Requests must be received by September 30, 2003. Or check the *Astronomy* Web site (www.astronomy.com) after February 2, 2004.

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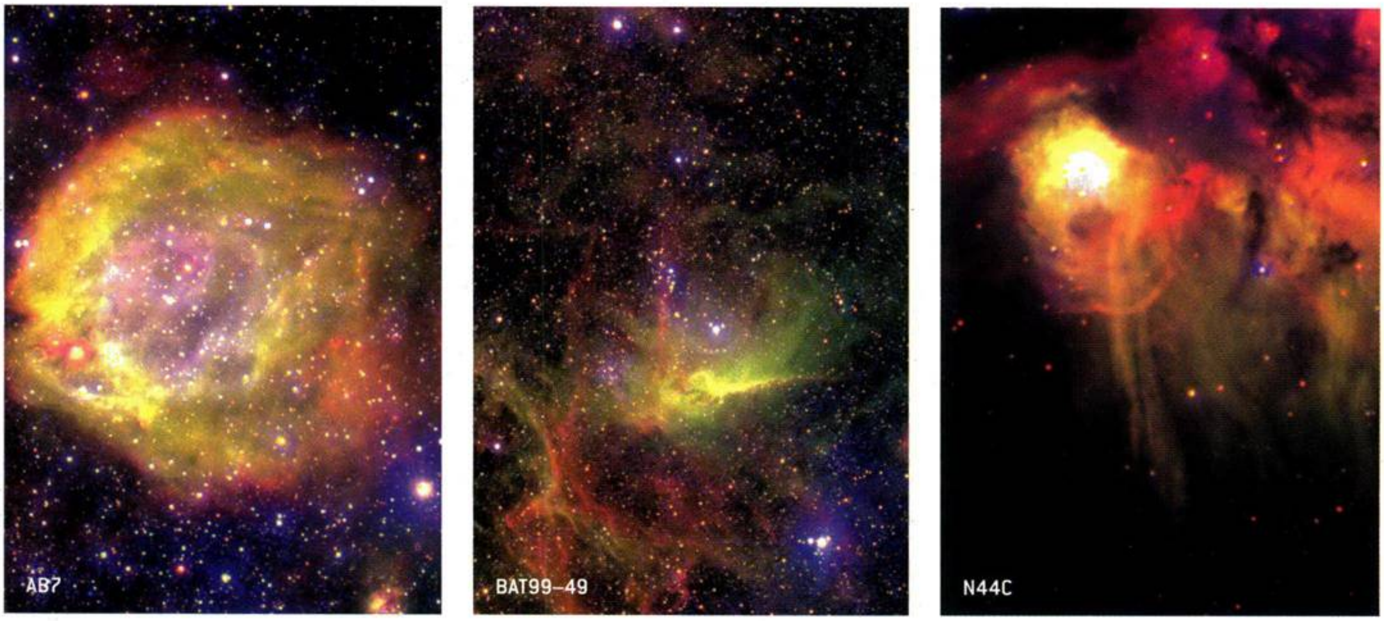
{ 08:03 } **A COLUMBIA RECOVERY OFFICE** will be established at Johnson Space Flight Center in Houston. As of April 15, when underwater searches in Texas ended, 70,000 items (36 percent of the Shuttle's weight) had been found.

news 08

Read all about it: Elliptical galaxies run naked, symmetry violated by fusion, an aging star's dust ring, NASA's nanotechnology, and active desktop astronomy.



IONS GLOW in nebulae that surround extremely hot stars in the Magellanic Clouds. These VLT pictures were created by combining images sensitive to singly ionized helium (468.4 nm, blue), doubly ionized oxygen (495.7+500.7 nm, green), and neutral hydrogen (656.2 nm, red). ESO

NEBULAE

Hot stars hide behind shrouds of gas

Some places in the universe contain hydrogen gas that glows brightly with colors corresponding to extremely high temperatures. These regions are so hot that hydrogen nuclei ionize. Called HII regions, these areas lurk in starburst galaxies and near ultraluminous x-ray sources in distant galaxies that emitted their light when the universe was young. To understand these far-flung, hot nebulae, we must look closer to home and see what nearby examples can tell us. Astronomers hope what they see close to home is the same as what exists out there.

In the Magellanic Clouds (two dwarf irregular galaxies residing just off the disk of the Milky Way) lie five HII regions that were imaged with the VLT MELIPAL telescope in Chile by a team led by Yaël Nazé of the Liège Institute, Belgium. Each nebula contains a star more than 20 times larger than the Sun with surface temperatures of a few tens of thousands of degrees. Three of these stars (AB7, BAT99–2 and BAT99–49) are Wolf-Rayet (WR) stars, which are highly evolved massive stars. One of these is the hottest WR star observed. A fourth nebula (N44C) contains a regular, very hot (O-type) star. Researchers believe this star has a companion — a white dwarf or other compact object — that created the nebula. — **PAMELA L. GAY**

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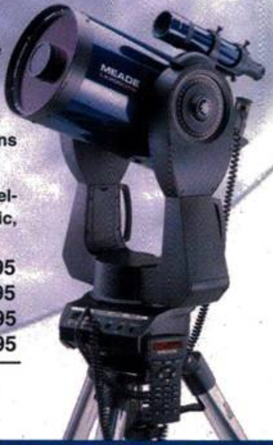

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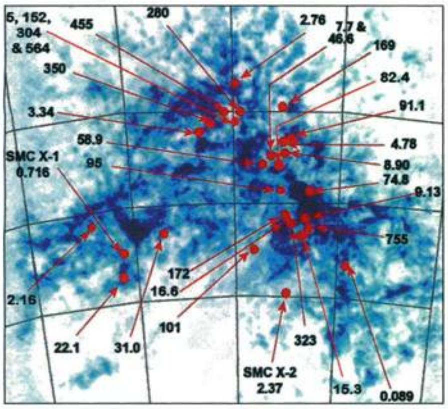
STELLAR EVOLUTION

Mass star death

When an entire generation of stars begins to die all at once, strange things can happen. Roughly one million years ago, our near galactic neighbor, the Small Magellanic Cloud (SMC), had a close encounter with the Large Magellanic Cloud. This triggered a burst of star formation in the SMC, and now many of the high-mass stars in that system are dying and becoming neutron stars. When neutron stars form pulsars in binary systems, violent things can happen.

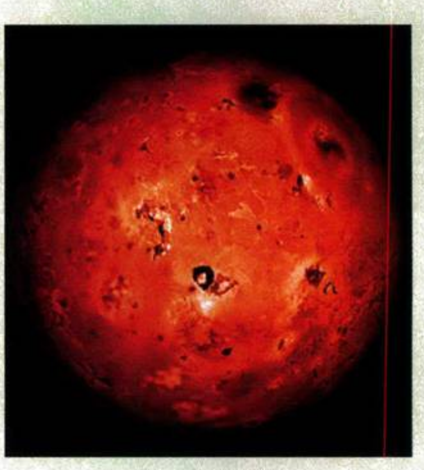


PULSARS MAKE THEIR PRESENCE KNOWN in the Small Magellanic Cloud. Pulsars are marked in red with their spin-periods given in seconds. MALCOLM COE

Malcolm Coe of the University of Southampton, England, and his colleagues monitored the SMC on a weekly basis for three years with the Rossi X-ray Timing Explorer. They found 36 binary systems where neutron stars triggered x-ray outbursts by stripping material off stellar companions. The neutron stars have rotation rates between a few seconds and thousands of seconds.

"We are finding two types of x-ray outbursts," explains Coe. Often, neutron stars outburst as they pass through the disk of material pulled off their companion. Larger outbursts also occur when the companion ejects material during its own evolutionary outbursts. According to Coe, "Most systems are identified for the first time while undergoing one of the larger outbursts." — **P. L. G.**

Io: Brought to you by the moon Ganymede and planet Jupiter



LAVA IN INFRARED shows regions that are hotter [light] and areas that are cooler [dark]. DAVID LE MIGNANT ET AL./KECK

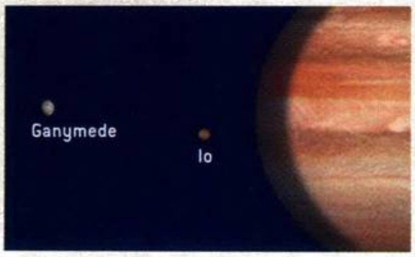
Jupiter and its moon Ganymede have teamed up to help astronomers obtain a rare view of another jovian moon, Io. University of California at Berkeley astronomer Imke de Pater and her colleagues took infrared images used to measure the temperatures of lava flows at dozens of Io's volcanoes. Image resolution was even sufficient to measure the temperature at the precise location where the lava comes up through Io's surface.

Io is the most geologically active object in the solar system. Interior heat, generated by tidal forces "kneading" the satellite, drives flows of molten magma to the surface. The resulting lava flows glow in the infrared. This wavelength of light does not pass easily through Earth's atmosphere and can be observed only by satellites or high-altitude telescopes like the 10-meter Keck II, on Mauna Kea, Hawaii, that de Pater and colleagues utilized.

Unfortunately, a good telescope alone was insufficient to acquire good data. Success required a chance celestial alignment as well.

Usually, reflected light from the Sun outshines Io's volcanoes. Until now, this interloping light interfered with accurate measurements of the wavelength, or color, of the volcanoes' maximum infrared radiation — data used to determine lava temperatures. To obtain the needed information, a way to block the Sun was required.

Luckily, Io often dives into Jupiter's shadow. But to make observations with sufficient resolution to distinguish volcanoes from their surroundings requires adaptive optics.



A PERFECT ALIGNMENT placed Io within Jupiter's shadow near a brightly glowing Ganymede. E. ROEN KELLY

Adaptive optics uses a bright object near the telescope's focus to determine how the atmosphere is moving. By flexing the telescope's mirror(s), the telescope compensates for this motion. For adaptive optics to work in this case, not only did Io need to be in Jupiter's shadow, but it also needed a nearby bright object.

On December 18, 2001, Ganymede was in just the right position to fill this role, and de Pater and her colleagues were ready and waiting with Keck II and its adaptive optics.

De Pater says the infrared light coming from most of Io's volcanoes show the brightness and wavelength distribution she expected if the volcanoes have a hot center and progressively cooler surroundings where older lava flowed. One hot spot, called Janus, appears more like a lava lake than a volcano. Measured lava temperatures indicate Io's lava may be similar in composition to lava from Earth's volcanoes.

De Pater announced these results at a joint meeting of the American Geological Union and two European Earth science organizations in Nice, France, in April 2003. — **BAS den HOND**

MARS GLOBAL SURVEYOR released 11,664 new images on April 4, 2003. These observations, made between February and July 2002, bring the on-line image total to more than 123,800. Images are at www.msss.com/moc_gallery.

DARK MATTER

Naked elliptical galaxies

Newly discovered "naked galaxies" that lack dark matter halos suggest the need to revise galaxy formation theories.

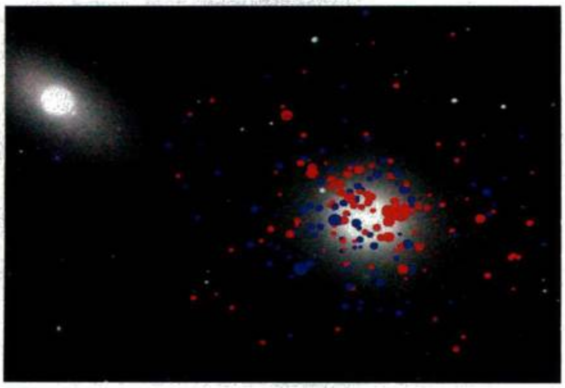
Initially, theorists proposed dark matter to explain why gas clouds orbit spiral galaxies faster than predicted. They assumed dark matter also surrounded elliptical galaxies but couldn't test this idea because ellipticals lack similar diagnostic clouds.

New observations disprove this assumption. A team led by Michael Merrifield and Aaron Romanowsky at England's University of Nottingham used a sensitive new spectrograph to track planetary nebulae — remnants of dying stars — orbiting five elliptical galaxies. Surprisingly, nebulae in three of the ellipticals showed no sign of acceleration by dark matter.

This challenges formation theories that require dark matter. "We have shown that dark matter in [galaxy] clusters is not concentrated in the elliptical galaxies that populate them," Merrifield says. "Any theory . . . must explain how ellipticals end up losing any dark matter they may have contained initially."

Naked galaxies may not pose the same challenges for Modified Newtonian Dynamics, an alternative to dark matter theory. Proposed by Mordehai Milgrom of the Weizmann Institute, MOND also explains galactic rotation. Milgrom's elliptical galaxy calculations show "no problem at all for MOND," at least so far.

Still, Merrifield foresees "significant cosmological implications" if more "naked galaxies" appear. — **ROBERT ADLER**



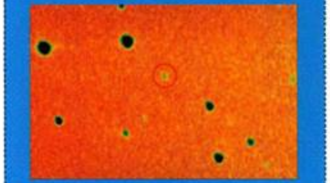
M105 WEARS NO DARK MATTER. Planetary nebulae moving toward the observer are marked in blue, and receding nebulae are marked with red. Higher velocity systems have larger marks.

2MASS/UMASS/IPAC-CALTECH/NASA/NSF

HIGH-ENERGY ASTRONOMY

An almighty burst

At 6:37A.M. E.S.T. (11:37 UT) on March 29, 2003, an explosion two billion light-years away outshone the entire universe in gamma rays for more than 30 seconds. A black hole was born.



GRB 030329 may have been briefly visible to the naked eye. DAVID STRANGE/WORTH HILL OBSERVATORY

NASA's High-Energy Transient Explorer satellite stood witness at this birth, which occurred when a massive star ended its life, exploding its outer layers while its core collapsed into a black hole.

The burst, GRB 030329, was one of the brightest and closest gamma-ray bursts ever detected. With a redshift of 0.168, it is the second-closest known GRB, and its intrinsic brightness puts it in the top one percent of all bursts. — **KELLY KIZER WHITT**

SURVEYS

Lost in space? Check the map

THE TARANTULA shines in infrared light from outside our galaxy. 2MASS/T. JARRETT, R. HURT

William Rand and Andrew McNally, founders of the popular map company Rand McNally, would be impressed. The Two Micron All Sky Survey (2MASS) completed an infrared survey of the entire sky. In the process, it mapped about 5 million images containing nearly a half-billion objects.

This grand effort to create an all-encompassing atlas of the sky began in June 1997. Using the 1.3-meter telescope at Whipple Observatory on Mount Hopkins in Arizona, 2MASS astronomers carefully scanned the Northern Hemisphere of the sky. In March 1998, a similar 1.3-meter telescope at Chile's Cerro Tololo Inter-American Observatory began charting the Southern Hemisphere. The final images were obtained in February 2001.

Scientists have spent the last two years organizing the data and preparing it for release.

A catalog of 2MASS images organized by subject can be accessed online at: www.ipac.caltech.edu/2mass/gallery/. — **MATT QUANDT**

THE SUN

Solar tadpoles

Earth-sized dark features shaped like tadpoles have been observed in the Sun's atmosphere. The first "tadpole" images were captured after a huge flare erupted on April 21, 2002. The flare released as much energy as a billion megaton nuclear bombs and heated the surrounding solar atmosphere to millions of degrees in minutes.

Astronomers hope that detection of these structures will shed light on a process known as magnetic reconnection, the mechanism astronomers believe powers explosions on the Sun. These events are carefully monitored because they disrupt satellite transmissions and power systems.

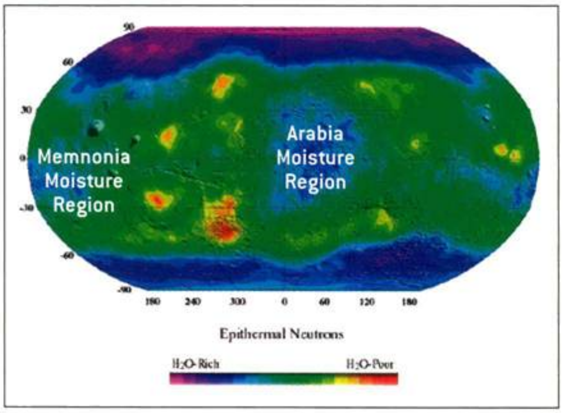
MILLION-DEGREE TADPOLE FEATURES the size of Earth form during massive solar flare explosions. NASA

TRACE, NASA's Transition Region and Coronal Explorer spacecraft, made the ultraviolet observation of the tadpoles. These objects are either dense plasma glowing in a color not detected by TRACE, or voids with very little plasma. — **MICHAEL E. BAKICH**

A NEW HORIZONS PLUTO-KUIPER BELT MISSION was approved by NASA in April 2003. It should launch January 2006 and reach the outer solar system in 2015. It will visit Pluto, Charon, and at least one Kuiper Belt object.

SOLAR SYSTEM

Mars's east & west poles



POSSIBLE FORMER POLES emit neutrons and gamma rays that are detected by the Mars Odyssey. The Arabia and Memnonia moisture regions are located on opposite sides of the martian globe. NASA/JPL/UNIVERSITY OF ARIZONA

Two areas along Mars's equator that are — relatively speaking — rich in water may be remnants of the Red Planet's former poles. Together with the present poles, these continent-sized areas stand out in Mars Odyssey observations. Instruments on this craft count neutrons and gamma rays kicked up from the top three feet of martian soil by cosmic rays. These detections suggest the presence of hydrogen, which in turn may indicate the presence of water in the soil.

Jeffrey Plaut of the Jet Propulsion Laboratory in Pasadena and Igor G. Mitrofanov of the Russian Academy of Sciences in Moscow reported these results and others from the first full year of Mars Odyssey observations at a meeting in Nice, France, in April 2003.

The areas with subsoil water have been baptized the Arabia Moisture Region and the Memnonia Moisture Region. In these areas, the soil is about 6 percent water by weight. This means water exists in the ground as ice, or that it is chemically bound to the soil. At the poles, water makes up 35 to 50 percent of the soil and is probably ice.

The two equatorial wet areas are opposite each other on the globe. Although this could be a coincidence, Mitrofanov said their relative location brings to mind claims that Mars once had an extremely large tilt. This could explain why Mars has wet regions that are observed by orbiters like Mars Odyssey. The moisture regions may be the sites of ice caps that formed when Mars was more inclined. Water from past poles may moisten these regions today. — **B. d. H.**

TDRS-1

Tracking at 20

Against all odds, the first Tracking and Data Relay Satellite (TDRS-1) celebrated its 20th year of service on April 4, 2003.

It was almost lost after a bad 1983 deployment from the Space Shuttle Challenger, but NASA engineers rescued the satellite by using its small, one-pound thrusters to guide it into a geosynchronous Earth orbit.

Since its salvation, TDRS-1 has been used in ways both its creators and its rescuers never anticipated, thus opening a new era of satellite communication.

One incident, among the many outstanding "firsts," stands out as the defining moment in TDRS-1's successful 20-year career. After staving off retirement in 1998, the ever-overachieving TDRS-1 was used for a medical emergency at McMurdo Station in Antarctica. Its high-speed connectivity allowed scientists to conduct a teleconference during which doctors in the United States successfully guided a welder through a real operation on a doctor diagnosed with breast cancer. — MATT QUANDT

HIGH-ENERGY PHYSICS

Broken symmetry makes helium

All rules are made to be broken, including the laws of physics. The subatomic pion particle breaks the charge symmetry rule that governs both fusion and decay.

In experiments performed at the Indiana University Cyclotron Laboratory, physicists forced heavy hydrogen (1 proton + 1 neutron) to fuse into helium in a controlled, measurable environment.

"Scientists have searched for this rare fusion process since the 1950s," says Indiana University physicist Edward Stephenson, the team leader. "The process would not happen at all if nature did not allow a small violation of what is known as charge symmetry.

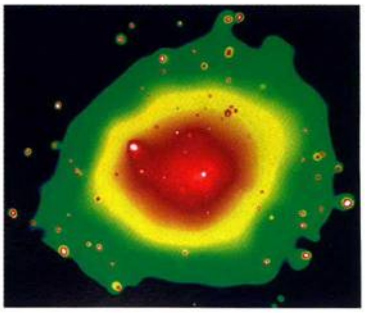
"If this symmetry violation had happened to be in the other direction, hydrogen would not have survived after the Big Bang, and the universe would not have the hydrogen fuel that keeps stars shining, including our Sun, making human life possible. Sometimes large consequences hang on delicate balances in nature." — **P. L. G.**

FOCUSING MAGNETS help capture helium. E. STEPHENSON

GALAXY CLUSTERS

Boogie-ing galaxies leave wakes

A vast ocean of gas exists in the space between galaxies in clusters. As galaxies surf through this material, they leave behind wakes of gas and create distortions in the intracluster sea. Some high-speed galaxies, traveling at supersonic speeds, create shockwaves like those of supersonic aircraft.



X-RAY OBSERVATIONS reveal the wakes of high-speed galaxies in this Chandra image of Abell 160. DAVID ACREMAN/CHANDRA

Astronomers studied these wakes and distortions from 29 galaxies in the galaxy cluster Abell 160 using the Chandra X-ray Observatory. "Abell 160 was an ideal cluster for this kind of study," says project astronomer David Acreman of the University of Birmingham. "It has the advantage that several bright galaxies are located near its center where Chandra can view them with a single observation." — **P. L. G.**

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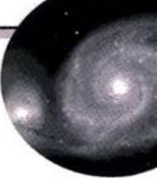

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EXTRAGALACTIC ASTRONOMY

Black hole breaks new galactic ground

Alex Filippenko of the University of California at Berkeley, and Luis Ho of the Carnegie Institution of Washington have found a supermassive black hole in an unexpected place — at the center of a "skinny" spiral galaxy named NGC 4395. The discovery proves that large galactic bulges are not a requirement for supermassive black holes.

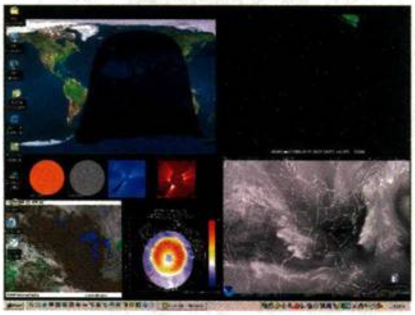
A BLACK HOLE HIDES in the bulgeless core of NGC 4395. This spiral galaxy's central black hole weighs 66,000 solar masses. A. SANDAGE/CARNEGIE INSTITUTION

"The supermassive black hole in NGC 4395 is the smallest one yet found in the center of a galaxy," says Filippenko. "This would be consistent with the galaxy having a small bulge. However, NGC 4395's bulge is not just small, it seems to be nonexistent."

The Keck I and ASCA (x-ray) telescopes measured the black hole at about 66,000 solar masses. "Here is an example of a massive black hole that is low in comparison to all previously reported supermassive ones, but it is definitely much more massive than stellar-class black holes and is located in a galaxy that has no bulge," says Ho.

The scientists suggest that the galaxy's diminutive core and modest supermassive black hole may represent an early evolutionary stage before central bulges and larger supermassive black holes have formed. — **KELLY KIZER WHITT**

Eyeing the world with an active desktop



KEEPING TRACK OF THE NIGHT and the weather makes your PC's "active desktop" an observing tool. DONALD GAY

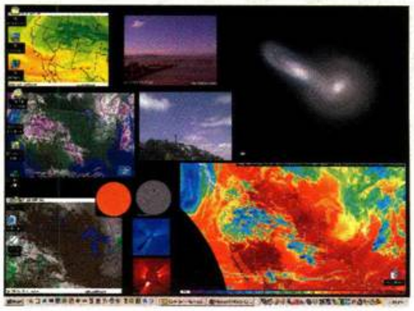
Many websites offer real time webcams, pictures that update every few minutes, world clocks, and other data that change with time. Anything in your browser can become part of your PC's "active desktop," allowing your screen to keep you up-to-date on weather (solar or local), news, and even your favorite picture-of-the-day.

Microsoft Windows has long had the ability to "automagically" refresh the desktop content. The active desktop capability creates eye-popping displays that bring the world to your monitor. This feature was introduced with Windows 98 and included in subsequent versions.

Web content is easy to add to the desktop. Simply find it on the web using your browser, then right-click on the picture and accept the option "Add as Desktop Item . . ."

Weather services, NASA, universities, and others offer real-time Earth images from satellites. Many images update several times per hour, and your desktop will show the latest images automatically. Some sites support zooming into the images, allowing you to see if your backyard or favorite viewing site has clear viewing.

Often, the most colorful images are weather maps generated from real time satellite data, such as those found online at www.accuweather.com and www.sec.noaa.gov/pmap/. These sites create Earth images based on visible and infrared images, radar, and other data such as water vapor. Install the WeatherBug (www.weatherbug.com) to receive audible alerts and information on violent weather in your area.



BRING YOUR BACKYARD TO LIFE on your screen by including local shots in your active desktop. DONALD GAY

Television and newspaper sites are also great sources for images of your local area, allowing you to virtually stick your head outside from your interior office or check if it's raining halfway across the country. For example, a Bay Area view can be found at www.abclocal.go.com/kgo/features/web_cam_main.html, while New York City is seen from www.earthcam.com/usa/newyork/timessquare/.

Planning a trip to Amundsen-Scott Station? South Pole weather is listed at www.phys.unsw.edu.au/southpolediaries/webcam.html.

For a less terrestrial view, the Sun shines at sohowww.nascom.nasa.gov and celestial shots are at mel.lib.mi.us/science/image.html.

Some good places for finding satellite views are www.goes.noaa.gov and www.ghcc.msfc.nasa.gov/GOES/. For views of satellites and other on-orbit info, see www.spaceflight.nasa.gov/realdata/index.html.

An interesting work in progress is the Bradford Robotic Telescope. When complete, this telescope could bring observing to your desktop. For more information, check its website at www.telescope.org/index.php, which includes webcam feeds. — **DONALD GAY**

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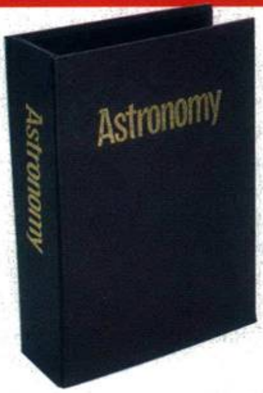

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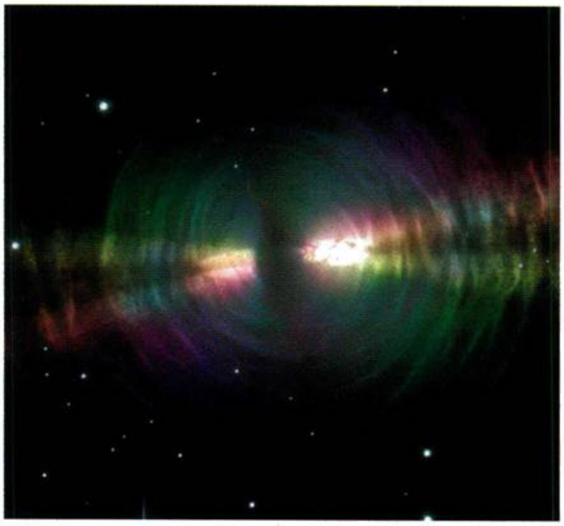
SATURN'S MOON COUNT GREW on April 8 when the International Astronomical Union acknowledged a small irregular moon orbiting the ringed world. S. Sheppard, D. Jewitt, and J. Kleyna took the discovery images on the 8.2-meter Subaru telescope, Hawaii.

HUBBLE HERITAGE IMAGE

Egg's scrambled light

An aging star hides behind a thick dust belt at the center of the Egg Nebula, 3,000 light-years from Earth in the constellation Cygnus. Concentric rings of dust, normally invisible, extend over one-tenth of a light-year from the star.



A HIDDEN CENTRAL STAR emits twin beams of light into the Egg Nebula's rings of dust, which are artificially colored to show how light reflects off soot-sized particles. NASA/HUBBLE HERITAGE

Dust around the star reflects light such that only waves vibrating in certain orientations reflect toward Earth. Polarizing filters on telescopes can be used to block all reflections except those aligned to the polarizing material at the nebula.

Polarizing filters used with Hubble's Advanced Camera for Surveys (ASC) accept only light vibrating at certain angles. In this composite image, light from three different filters has been colored to demonstrate how dust scatters the light. Where the light appears to be white, in the innermost portions of the nebula, the dust is thicker and scatters light many times in random directions.

Polarized light from the Egg Nebula provides scientists with information about the dust particles' sizes and allows them to pinpoint the exact location of the nebula's hidden central star. Most of the fine dust is made of carbon manufactured by fusion in the star's heart and ejected into space as the star ages. These dust grains are essential for building dusty disks around future generations of young stars, and may be important in the formation of planets around those stars. — **LAURA WILLIAMS**

INSTRUMENTS

Tubular computing

NASA scientists have developed a new method for interconnecting integrated circuit parts using nanotubes. This process substantially shrinks circuits. "NASA needs high-performance computing in small packages for future autonomous spacecraft," says Meyya Meyyappan of NASA Ames Research Center in California. "Computer chips with more layers and smaller components can do more for us."

This process involves the chemical synthesis of carbon nanotubes in place of copper circuits. Nanotubes can be smaller because they don't suffer as much as copper does from current deterioration. The process eliminates the need to etch the silicon to hold the copper, since the nanotubes are grown on the surface. — MATT DUNN

NANOTUBES GROW where copper once was etched. D. SRIVASTAVA

GLOBAL WARMING

Last century not so hot

A new study shows the 20th century was not the warmest century or the century with the most extreme weather during the past 1,000 years. A team led by Smithsonian astronomers Willie Soon and Sallie Baliunas reviewed more than 200 climate studies published since 1960 for their report.

The study confirmed two significant climate periods in the last thousand years, the Little Ice Age (1300–1900 A.D.) and the Medieval Warm Period (800–1300 A.D.). Many indicators showed the medieval warmth to be greater than that of the 20th century.

CORAL REEFS indicate the 20th century was not the hottest. DAVID A. AGUILAR/CFA

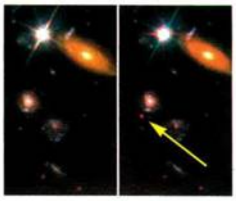
The team, working as forensic detectives, analyzed climate indicators including tree-ring growth, cultural data, glacier movement, corals, pollen, river and seafloor sediments, and more.

"For a long time, researchers have possessed anecdotal evidence supporting the existence of these climate extremes," says Baliunas. "Now we have an accumulation of objective data to back up these cultural indicators." — **M. E. B.**

HUBBLE INSTRUMENTS

Crystal-clear supernovae

The Hubble Space Telescope's new Advanced Camera for Surveys (ACS) has discovered its first two remote supernovae. Designated SN2002dc and SN2002dd, these type Ia supernovae are located about 4.7 billion and 7.6 billion light-years from Earth, respectively.



SN2002dd IS CAUGHT on disk by Hubble's new ACS. NASA/J. BLAKESLEE AND Z. LEVAY

Found in the Hubble Deep Field region of Ursa Major, the supernovae aren't the most distant ones ever seen. However, the ACS is offering the best-ever look at such faraway objects. Astronomers suspect the more remote supernova may belong to a time when the universe's expansion rate was transitioning from a gravity-induced slowdown to its current state of acceleration caused by dark energy, a mysterious, negative-gravity force.

"This beautifully demonstrates that the ACS is a 'supernova machine' for probing the early universe," says Johns Hopkins University astronomer Holland Ford, a co-author on the discoveries.

— **VANESSA THOMAS**

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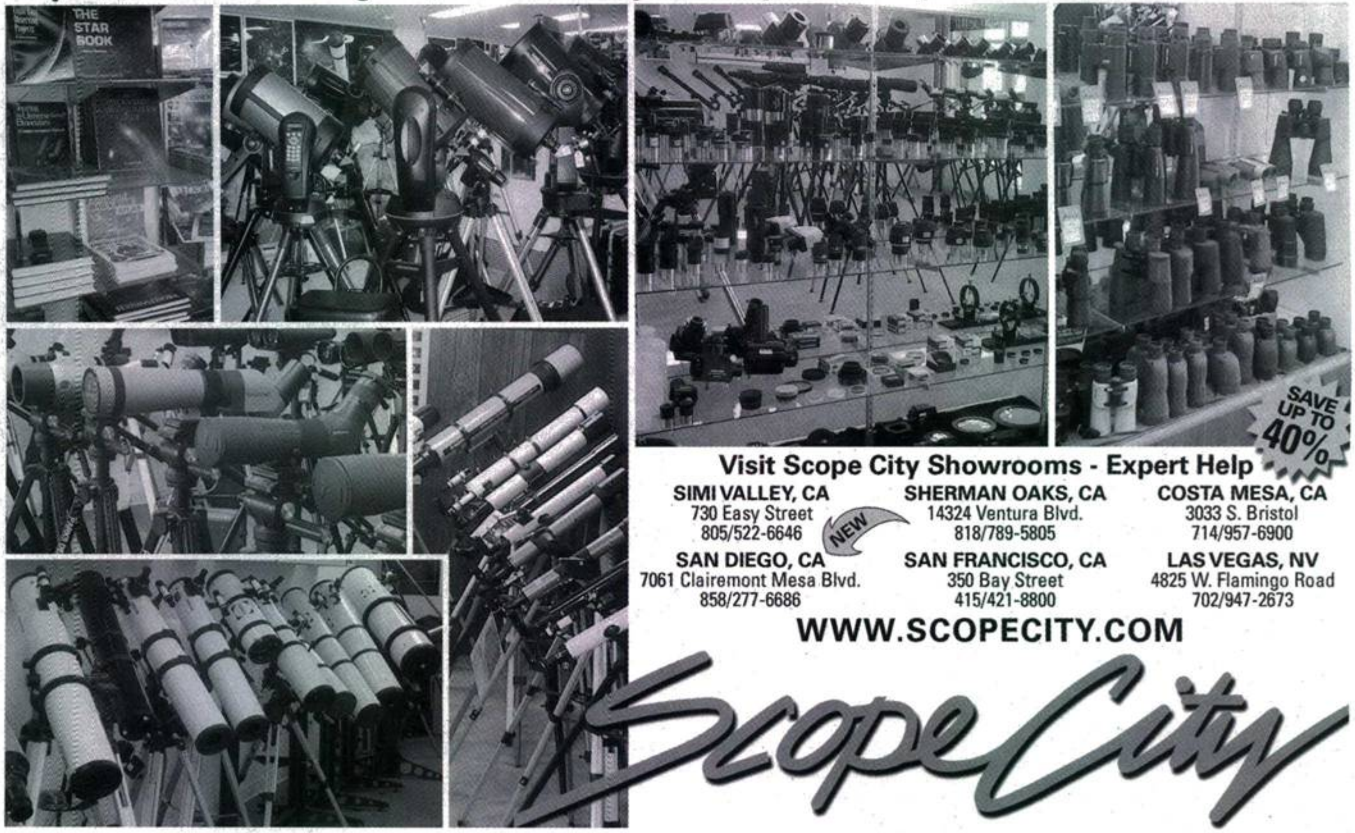

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1.25" – $99.95 • Brandon 1.25" – $99.95 • 48mm – $199.95 • Visual Back – $199.95

SOLAR PROMINENCE FILTERS

The 1.5 Ang. Lumicon Solar Prominence Filter system lets you see the awe-inspiring solar prominences jutting of off the edge of the sun. Sunspots and bright filaments can also be seen on the sun's surface. The filter has a 2" barrel for insertion into 2" focusers, and can be easily adapted for 1.25". It also has camera T-threads and a viewing adapter for 1.25" eyepieces.

Solar Prominence Filter $699.95 • 58mm Energy Reject Prefilter – $169.95 • 77mm Energy Reject Prefilter – $199.95

Off-Axis Mask for 8" SCT – $69.95 • Off-Axis Mask for Meade 10" – $89.95 • Off-Axis Mask for C11 – $99.95 • Off-Axis Mask for 12" LX200 – $99.95 • Off-Axis Mask for C14 – $119.95 • Off-Axis Mask for M14 – $119.95 • Off-Axis Mask for 16" LX200 – $129.95

MULTIPLE FILTER SELECTOR

The Lumicon 1.25" Multiple Filter Selector lets you switch instantly back and forth between your Lumicon 1.25" filters without having to constantly thread and unthread them from your eyepieces. You may leave one of the 5 slots open to compare views with and without your Lumicon filters. – $129.95

EASY GUIDERS

All of Lumicon's famous off-axis guiders feature Lumicon's patented radial and rotational off-axis adjustments – combined with a large off-axis pick-off prism making bright guide star selection a breeze.

CASSEGRAIN EASY GUIDER FOR 7" TO 9.25" SCTs

The Lumicon Cassegrain Easy Guider allows off-axis guiding with your Cassegrain telescope, reducing the f-ratio from f10 to f6.3 with a large, fully coated focal reducing lens. The faster f-ratio combined with the ease in finding and guiding on bright guide stars minimizes guiding error making for successful astrophotos. Threaded for 48mm filtering. Specify camera type when ordering.

Celestron 5 – $249.95 • 7" Mak – $249.95 • 8" SCTs – $249.95 • Celestron 9.25" – $249.95

GIANT EASY GUIDER FOR 10" TO 16" SCTs

The Lumicon Giant Easy-Guider is a powerful photo/visual tool utilizing a 80mm multicoated compression lens, reducing the f-ratio from f10 to f6.3, allowing you to take full advantage of your telescope's capabilities. Ideal for 35mm and 120 format film with 100% edge-to-edge illumination with pinpoint star images. All other off-axis guiders have prisms and focal reducing lenses a fraction the size of the Lumicon Giant Easy Guider's. Threaded for all Lumicon 48mm filters. Specify camera type when ordering.

10", 12", 14" and 16" Meade – $399.95 (Meade 16" LX200 requires adapter - $169.95) • 11" and 14" Celestron – $399.95

NEWTONIAN AND REFRACTOR EASY GUIDER

The Lumicon Newtonian and Refractor Easy Guiders allow off-axis guiding directly through the main telescope, thus preventing differential flexure that can occur between your telescope and guide scope that can ruin your astrophotos. Low-profile design installs in seconds into 1.25" and 2" focusers. Threaded for 1.25" and 48mm filters. Specify camera type when ordering.

1.25" and 2" Newtonian – $189.95 • 1.25" and 2" Refractor – $189.95

LUMICON EASY GUIDER ACCESSORIES

- Newtonian Easy-Guider Focal Reducer Lens in Cell – $79.95
- Giant Easy-Guider Focal Reducer Lens in Cell – $199.95
- Giant Easy-Guider - No Lens – $319.95
- Cassegrain Easy-Guider - No Lens – $219.95

LUMICON 3X RELAY DIAGONAL FOR USE WITH EASY GUIDERS

Lumicon Relay Diagonal's 3x Barlow lens increases the guiding magnification in the off-axis portion of your Lumicon Easy-Guider, increasing off-axis guiding ease and precision. – $99.95

HYPER KITS

LUMICON FILM HYPERSENSITIZATION KITS

Film hypersensitization with a Lumicon Hyper-Kit super-dries your film's emulsion using nitrogen and hydrogen (Lumicon's Forming Gas: 8% prepurified hydrogen, 92% prep. nitrogen, removing ALL water vapor and oxygen molecules, thus thermally stabilizing the film's emulsion. The process also 'soaks' the emulsion with hydrogen, thus sensitizing the silver halide crystals, making them more sensitive to faint light. The combined effect reduces reciprocity failure of the film, allowing it to remain sensitive to light well beyond an hour instead of only a few minutes. Hypered film is a MUST for anyone who is serious about taking deep-sky photographs.

LUMICON MODEL 300 FILM HYPERSENSITIZATION KIT FOR 35MM AND 120 FILM

For simplest hypering with film still in its metal cassette, the Model 300 Hyper-Kit is easy and safe for your film. Operates with Lumicon's Forming gas at 30°. Film may be hypered in two to five days.

Chamber Only – $249.95 • Film Hyper Kit – $375.95 • Hyper Kit O-Ring Set – $9.95

LUMICON MODEL 600 FILM HYPERSENSITIZATION KIT FOR 35MM AND 120 FILM

The versatile Lumicon Model 600 Hyper-Kit is capable of hypering film either while still in its metal cassette at 30° C, or more quickly with highest saturation on the open reel at 50° C. Super-dries and sensitizes the film's emulsion with Lumicon's Forming Gas.

Chamber Only – $299.95 • Film Hyper Kit – $475.95 • Hyper Kit O-Ring Set – $9.95 • Hyper Kit Hand Vacuum Pump – $39.95 • Hyper Kit Vacuum Pump Handle – $9.95

LUMICON MODEL 1200 FILM HYPERSENSITIZATION KIT FOR 35MM, 120 AND 4x5 FILM

Large-capacity Lumicon Model 1200 Hyper-Kit accepts 4x5 film. Kit is capable of hypering film in just 12-to-20 hours with highest saturation. Super-dries and sensitizes the film's emulsion with Lumicon's Forming Gas at either 30° or 50° Centigrade for simple or advanced modes of operation.

Chamber Only – $379.95 • Film Hyper Kit – $751.95 • 4x5 Plate Holders – $99.95 • Hyper Kit O-Ring Set – $9.95

HYPER KIT ACCESSORIES

- 4x5 Sheet Film holder – $99.95
- 35L Cylinder of Forming Gas – $145.95
- 30° C Temperature Sensor Probe – $99.95
- 50° C Temperature Sensor Probe – $99.95 • Temperature Controller – $139.95 • Electric Vacuum Pump – $349.95 • 220 V option on Vacuum Pump – $44.95 • 220V/110V Converter – $29.95 • Vac/Pressure Hose with Clamp – $9.95

ASTROPHOTOGRAPHY FILM

HYPERED FILMS

Use Lumicon Hypersensitized Film to take stunning astro photographs. This allows you to expose film on your favorite deep sky object far longer, with no fog buildup, than does non-hypersensitized film.

Fuji G800 – $19.95 • Fuji RD100 – $14.95 • TP2415 B&W – $19.95 • TP6415, 120 – $19.95 • Kodak P1600 – $24.95 • Kodak PPF400 – $19.95 • Kodak PPF400, 120 – $19.95

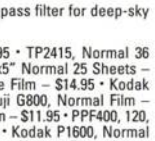
NON-HYPERED FILM

Lumicon's high-contrast, extremely fine-grained film. High quality for medium-format astrophotography.

Use with Lumicon's H-alpha pass filter for deep-sky photos.

TP2415, Bulk 150' Roll – $79.95 • TP2415, Normal 36 exposure – $11.95 • TP4415, 4x5" Normal 25 Sheets – $49.95 • SO-279 Vericolor Slide Film – $14.95 • Kodak 6415, Normal Film – $9.95 • Fuji G800, Normal Film – $9.95 • PPF400, 120, Normal Film – $11.95 • PPF400, 120, Normal Film - 5 pack – $49.95 • Kodak P1600, Normal Film – $19.95 • Fuji Sensia RD100, Normal Film – $9.95

FILM DEVELOPING MATERIALS



- Film Changing Bag – $ 16.95
- Kodak D19 B&W Developer – $ 19.95
- Patterson film-developing tank – $19.95

DIAGONALS

ENHANCED ALUMINUM STAR DIAGONALS

The Lumicon Enhanced Aluminum Star Diagonal reflects 96 to 97 percent of the light from the telescope's primary optics into your eyepiece. Its single 1/10 wave precision-polished surface is superior to the three surfaces of prism diagonals, and its enhanced coating is more durable than a standard aluminum coating. Lumicon collimates each star diagonal using a double-pass collimator, ensuring that the light reflected from the diagonal is perfectly perpendicular to the telescope's optical axis.

1.25" – $99.95 • 2" – $189.95

LUMIBRITE STAR DIAGONAL

The Lumicon LumiBrite Dielectric-Coated Diagonal reflects >98 percent of the light from the telescope's primary optics into your eyepiece. Not only is the Dielectric Coating more durable than a standard aluminum coating, it is also smoother, resulting in higher image contrast. 1.25" – $149.95 • 2" – $239.95

SKY VECTOR

The Lumicon Sky Vector is a state-of-the-art digital setting circle system, providing virtually any astronomical telescope, whether equatorial or altazimuth, with a continuous, real-time digital readout of right ascension and declination coordinates. With the Sky Vector, you will be able to find objects even faster than with most fully computer-driven telescopes. It's alphanumeric display uses a simple, easy-to-read scrolling text format. There is no need to polar align or to enter Latitude, Longitude, Date, Altitude, and Sidereal time – just initialize on one or two stars and you're ready to go!

SKY VECTOR 1

The Lumicon Sky Vector 1 features: One-or-two-star Initialization; 4000-step encoders for high resolution accuracy (0.09 deg.); Digital Right Ascension coordinate readout to 1 arc-minute; Digital Declination readout to 10 arc-minutes; Guide mode for guiding you to the selected object in current memory; The Lumicon Sky Vector 1's memory has over 220 of the finest objects in the sky including the famed "Messier Catalog."

Complete Set – $349.95 • Kit only – $269.95

LUMICON NGC SKY VECTOR

The Lumicon NGC Sky Vector has all the features of the Sky Vector 1, plus a large 12,000-object database, higher resolution display modes, IDENTIFY mode, and current constellation and current chart number displays - all on a 16 digit red LED display. It can be integrated with a personal computer for display of celestial object coordinates.

Complete Set – $489.95 • Kit only – $419.95 • Serial Cable – $29.95

SKY VECTOR UPGRADES

- Upgrade 3.65 Chip Set for NGC Sky Vector. – $59.95
- 8192-Step Encoder (Set of 2). Can be purchased separately or in place of the standard 4000 step encoders. – $29.95

LUMICON SKY VECTOR HARDWARE PACKAGES

Lumicon Sky Vector Hardware Package for Meade and Celestron SCT's includes: declination encoder bracket, right ascension encoder holder, encoder shaft holders, Allen wrench, and instructions.

Lumicon Sky Vector Hardware Package for Dobsonian telescopes includes: Brass Azimuth Bolt, Stainless Steel Azimuth Encoder Bracket, Aluminum Altitude-Encoder-Shaft Holder, Stainless Steel Altitude Encoder Bracket, 10 wood screws, Allen wrench, and instructions.

C5+ – $79.95 • C8 – $69.95 • Celestar 8 – $79.95 • Celestar 8 Dlx – $79.95 • G8/G11 – $349.95 • Ultima 8 – $79.95 • Ultima 11 – $99.95 • C11 – $79.95 • C14 – $129.95 • Meade 2080 – $69.95 • 2120 – $79.95 • 8" Dob – $69.95 • 10" Dob – $69.95 • 12/13" Dob – $79.95 • 16/17" Dob – $89.95 • CI700 – $299.95

RICHFIELD VIEWERS

RICHFIELD VIEWER FOR 7" TO 9" SCTS

The Lumicon Richfield Viewer takes your Schmidt-Cassegrain's f/10 optics and reduces them to f/6.3 for beautiful wide-field views. Its fully-coated 50mm diameter focal reducing lens has a larger clear aperture and less coma than higher-priced focal reducers on the market, providing superb unvignetted views. Barrel acepts 2" star diagonals. Comes with an aluminum 2"-1.25" eyepiece reducer, threaded for 48mm filters. – $99.95

RICHFIELD VIEWER, THREADED FOR 7" TO 9.25" SCTs

Threads directly into telescope. – $99.95

RICHFIELD VIEWER, SLIDE-ON, FOR 7" TO 9.25" SCTs

For attachment onto SCTs that have the Lumicon Easy-Guider threaded attachment ring in place. Slides over attachment ring. – $99.95

GIANT RICH-FIELD VIEWERS

LUMICON GIANT RICH-FIELD VIEWER FOR LARGE SCTs

Takes your large Schmidt-Cassegrain f/10 optics and reduces them to f/6.5 for the widest possible views of large galaxies like M31, M33 and NGC 253, and pairs of galaxies like M81and M82. Moving the 80mm diameter focal reducing lens to the forward position in the Rich-Field Viewer body yields an even wider field. Comes with a 2"-1.25" eyepiece reducer, threaded for 48mm filters.

10" SCTs – $279.95 • Celestron 11" – $279.95 • 12" SCTs – $279.95

LUMICON 2.5X CCD COMPRESSOR

This cost-effective, fully-coated lens widens the telescope field and yields pinpoint star images for small to medium-size CCD cameras. Has male threads for 1.25" eyepiece (1.120"x40) or camera-type barrels. – $129.95

LUMICON 48MM COMA CORRECTOR/FIELD FLATTENER FOR NEWTONIAN EASY GUIDER OR 2" EYEPIECE

The Lumicon Coma Corrector / Field Flattener Lens dramatically reduces coma and flattens the field when used, in particular, with f/3.5 to f/6 Newtonian telescopes. Off-axis star images are made much smaller, thus improving photographic quality and making guiding much easier. Free of all chromatic aberration and fully multi-coated to prevent ghost images. Can be used on all 48mm threaded accessories. Neither shrinks nor magnifies the image. – $239.95

LUMICON 1.5x–1.8x MULTIPLIER/FIELD FLATTENER

The Lumicon Multiplier / Field Flattener Lens has been custom computer-designed to increase image scale with the flattest field possible for photography and visual use with fast Newtonian Telescopes. This lens is suitable for use with f/3.5 to f/6 systems. Fully multicoated for maximum light transmission. – $259.95

FINDERSCOPE

Lumicon high quality 50mm SuperFinder – Comes complete with 1.25", 25mm cross-hair eyepiece.

The Lumicon 80mm SuperFinder for Right-Angle viewing. This finder telescope actually lets you see many of the deep-sky objects you are looking for, complementing any telescope having 8 or more inches of aperture. It also makes for a wonderful rich-field telescope for beautiful views of the Milky Way. Comes with 1.25", 25mm cross-hair eyepiece and helical drawtube-type focuser.

50mm RA Finder - Body Only – $79.95 • 50mm RA Finder - Complete – $149.95 • 50mm Straight Thru Finder - Body Only – $79.95 • 50mm Straight Thru Finder - complete – $119.95 • 80mm Right Angle Super Finder – $199.95 • 80mm Right Angle Super Finder with Tripod Block – $219.95 • 80mm Right Angle Super Finder - Complete – $299.95 • 80mm Straight Thru Super Finderscope – $199.95

FINDERSCOPE BRACKETS

This two-ring finder bracket firmly holds finderscopes to your telescope while allowing precise alignment with the main optical axis. The base is radius-cut to fit snugly against the telescope's main tube, and the dovetail groove makes it easy to install or remove the finderscope from the base. Fastens in brand name SCT telescope mounting holes.

- 50mm Finder Bracket, 8", 10/11", and 14" – $49.95
- 80mm Finder Bracket, 8", 10/11", and 14" – $59.95

- Universal Dovetail Bracket for 50mm finder – $39.95
- 2 ring traditional universal brackets for 50mm finder – $19.95

LUMICON 25MM CROSS-HAIR FINDER EYEPIECE

This well-made 25mm Kellner single-crosshair finderscope eyepiece is ideally suited for Lumicon's 50mm and 80mm Super-Finders. High contrast and flat field. Non-illuminated. – $69.95

GUIDING EYEPIECE

LUMICON GUIDING EYEPIECE WITH RETICLE ILLUMINATOR

Lumicon's top-quality 12.5mm 1.25" Orthoscopic eyepiece with focusable dual cross hair for precision guiding. Incorporates new state-of-the-art cordless Reticle Illuminator, featuring rheostatic brightness control and on/off switch.

12.5mm 1.25" Illuminated Reticle E.P. – $149.95 • Pulseguider Illuminator – $42.95

BINOVIEW

LUMICON BINOVIEW

These new high-quality German-made binoviews employ Grade-A BK-7 crown glass for its precision-polished prisms. Ordinarily, BaK 4 is used as a recourse to improve color correction, but in these binoviews color correction is so good that we may use the most transparent, homogeneous, bubble-free crown glass available – BK-7. Clear aperture is 22mm. Its straight-through design employs superior roof prisms for image erection. Each prism surface is multicoated for the highest transmission of light and freedom from ghosts. Focuser travel is 20mm. – $699.95

VISUAL AND PHOTOGRAPHIC ACCESSORIES

PHOTOGRAPHIC ADAPTERS

1.25" Prime Focus Adapter – $24.95 • 2" Accessory Adapter for Celestron Classic Refractors – $39.95 • 2" Accessory Adapter for Celestron Fluorite Refractors – $39.95 • .96" Prime Focus Adapter – $19.95 • Basic Camera Adapter 1.25" – $39.95 • Basic Camera Adapter .965" – $39.95 • Adapter to mount Mamiya 645 Camera to 2" – $149.95 • 2' to T-thread adapter – $29.95 • Tele-Extender – $29.95

VISUAL ADAPTERS

1" Thread-in extension tube, 1.25" – $19.95 • 1.25" Focuser to .96" Eyepiece Adpter – $24.95 • 2" Length drop-in Extension Tube 1.25" – $19.95 • 4.5" Length Drop-in Extension Tube, 1.25" – $29.95 • 2" Long Thread-in Extension tube, 2" Diameter – $24.95 • 2" Long, 2" Diameter Drop-in Extension Tube – $24.95 • 3" Long, 2" Diameter Drop-in Extension Tube – $24.95 • 2" to 1.25" Reducer – $24.95 • 2" Accessory Adapter for C6 – $39.95 • 2" Accessory Adapter for Schmidt Cassegrains – $39.95 • 2" Accessory Adapter for Celestron Classic Refractors – $39.95 • 2" Accessory Adapter for Celestron Fluorite Refractors – $39.95 • Adapter for .96" focuser and 1.25" Eyepiece – $24.95 • f/10 Viewing Adapter for Giant Easy Guider – $89.95 • Adapter for Meade 2" Thread-on diagonal to Cass. Easy Guider – $39.95 • Adapter for Meade 2" Thread-on diagonal to Giant Easy Guider – $49.95 • Adapter to hold 1.25" Eyepiece on T-thread – $29.95 • Adapter to hold 2' eyepiece on T-thread – $49.95

EASY GUIDER ADAPTERS

Adapter to mount Hasselblad Camera to Giant Guider – $449.95 • Adapter to mount Pentax 645 Camera to Giant Guider – $169.95 • Adapter to mount Pentax 6x7 Camera to Giant Guider – $149.95 • 16" LX200 adapter for Giant Guider – $169.95 • Adapter to mount Hasselblad Camera to Cass. Easy Guider – $349.95 • Adapter to mount Pentax 645 Camera to Cass. Easy Guider – $159.95 • Adapter to mount Pentax 6x7 Camera to Cass. Easy Guider – $139.95

STEP RINGS

48mm to 46mm – $11.95 • 48mm to 49mm – $11.95 • 49mm to 48mm – $11.95 • 52mm to 48mm – $11.95 • 52mm to 58mm – $11.95 • 55mm to 48mm – $12.95 • 55mm to 58mm – $12.95 • 58mm to 48mm – $12.95 • 62mm to 58mm – $12.95 • 62mm to 72mm – $14.95 • 67mm to 62mm – $15.95 • 67mm to 72mm – $15.95 • 67mm to 77mm – $15.95 • 72mm to 67mm – $15.95 • 72mm to 77mm – $15.95 • 77mm to 67mm – $15.95 • 77mm to 72mm – $15.95 • 82mm to 77mm – $15.95

LUMICON ADJUSTABLE PIGGYBACK MOUNTS

Lumicon Deluxe Piggyback Mounts allow you to mount the Lumicon Super Finder, other small telescopes, or cameras having 1⁄4-20 threaded mounting blocks, onto medium and large telescopes. The Piggyback Mounts are adjustable in altitude and azimuth, thus allowing you to align your optics with the optics of your main telescope. Each of the four available Piggyback mount bases have their own radius cut, allowing a solid flush mount to your telescope's main tube.

6" – $59.95 • 8" S.C.T.s – $59.95 • 10/11" S.C.T. – $59.95 • Celestron C14 – $59.95

MISCELLANEOUS ACCESSORIES

HELICAL FOCUSERS

Lumicon Helical Focuser, 1.25" and 2.00" for tube O.D.s 7.5", 9.5", 12.5", 16", and 20". Also flat base or specially for Odyssey.

1.25" Helical Focusers 7.5" – $69.95 • 1.25" Helical Focusers 9.5" – $69.95 • 1.25" Helical Focusers 12.5" – $69.95 • 1.25" Helical Focusers 16" – $69.95 • 1.25" Helical Focusers 20" – $69.95 • 1.25" Helical Focusers, Flat Base – $69.95 • 1.25" Helical Focusers, Odyssey – $69.95 • 2.00" Helical Focusers 7.5" – $99.95 • 2.00" Helical Focusers 9.5" – $99.95 • 2.00" Helical Focusers 12.5" – $99.95 • 2.00" Helical Focusers 16" – $99.95 • 2.00" Helical Focusers 20" – $99.95 • 2.00" Helical Focusers, Flat Base – $99.95 • 2.00" Helical Focusers, Odyssey – $99.95

VINYL DUST COVERS AND PLUGS

1.25" – $6.95 • 1.3" – $6.95 • 1.5" – $6.95 • 2" – $6.95 • 2.1" – $7.95 *(all these prices for a set of four)* • 5.5" – $7.95 • 6.7" – $9.95 • 7.5" – $12.95 • 9.5" – $17.95 • 10.3" – $17.95 • 12.5" – $23.95 • 12.8" $23.95 • 15" – $35.95 • 15.6" – $36.95 • 16" – $37.95 • 19" – $42.95 • 21" – $45.95 • 1.25" Plastic Dust Plug – $6.95 • 2" Plastic Dust Plug – $8.95 • 3.5" Plastic Dust Plug – $6.95 *(all these prices for each piece).*

LUMICON LUMILITE RED LED FLASHLIGHT

The Lumicon Red LED Flashlight not only provides the proper illumination for star atlases, but also for walking in the dark when held at or below belt level. Has built-in resistor for energy conservation – If you accidentally leave it on when you pack up, its batteries will still be almost as good as new in the morning! Great for astronomers, submariners or pilots who need to preserve their night vision. – $14.95

BARLOWS

Lumicon 2x Barlow 1.25" – $39.95
Lumicon 2x Barlow 1.25" Thread-in Barlow – $79.95

12" CAMERA CABLE RELEASE

Self-locking 12" Camera Cable Release for timed exposure. This high quality vinyl-covered cable release prevents camera shutter vibrations on long exposure photographs – a must for astrophotography. – $19.95

COLLIMATORS

Lumicon Cheshire Collimator for Laser – $39.95
Lumicon red LED Laser Collimator – $99.95

LUMICON 6X CRITICAL FOCUS SCOPE, HAND-HELD

This simple accessory will magnify by 6x stars that are seen through your camera's viewfinder allowing you to more easily determine when best focus has been achieved. – $19.95

SECONDARY MIRRORS

1/10 Wave flatness fine-annealed low expansion Pyrex.

ENHANCED Aluminum >96 reflectivity.

1.33" – $49.95 • 1.55" – $59.95 • 1.83" – 79.95 • 2.60" – $129.95

LUMIBRITE Dielectric Coating >98%

1.33" – $99.95 • 1.83" – $149.95

FILTERS AND LENS CLEANING KIT

Includes: Cleaning Fluid, Lens Cleaning Tissue, Ultra Brush Dust Remover, Blower Brush, Q-Tips – $19.95

HOW TO ORDER

You can order on line; please visit our website at **www.lumicon.com**, or you can order direct from us by calling 805/520-0047, 800/420-0255 or fax 805/520-3030; Credit Card accepted. You can also buy Lumicon products by visiting the showroom of your favorite authorized Lumicon astronomy retailer. All products are subject to shipping and handling charges and sales tax if applicable. Please call us or visit Lumicon's website for more details.

LUMICON

Lumicon International
A division of Parks Optical
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Martian chronicles

Astronomers' ideas about the Red Planet have undergone radical changes in the past 400 years. /// BY GEOFF CHESTER

My first glimpse of Mars came in 1960, when I happened upon the 1949 edition of *The Conquest of Space* by Willy Ley. The color plates in the center of the book included a wonderful view of Mars as seen from its outer moon, Deimos, rendered by the visionary space artist Chesley Bonestell. The artist depicted a dusky pink world, hanging in the blackness of space, with white polar caps and tantalizing greenish patches and streaks. This image, along with Bonestell's equally imaginative views of other planets, made me realize that some of those bright lights in the night sky were actual places awaiting the attention of future explorers. I yearned to be one of those explorers.

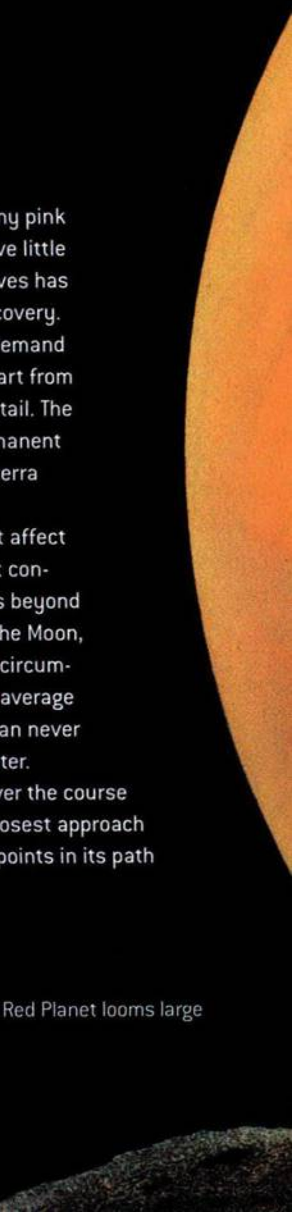
My first glimpse of the real Mars came on a crisp February night a few years later, when I directed my new 60mm refractor to the bright ruddy glimmer that hung in the New England sky. Expecting to see the world depicted in the Bonestell painting, I was greeted instead by a view of a tiny pink dot. A wave of disappointment washed over me, and my urge to explore this dancing blob quickly waned in the evening's chill.

But as the years went by, the biennial apparitions of the Red Planet still beckoned. As my observing skills (and the quality of the telescopes available to me) improved, the tiny pink dot began to reveal its secrets to my persistent gaze. I have little doubt that most everyone who has seen Mars for themselves has followed a similar path from initial letdown to thrilling discovery.

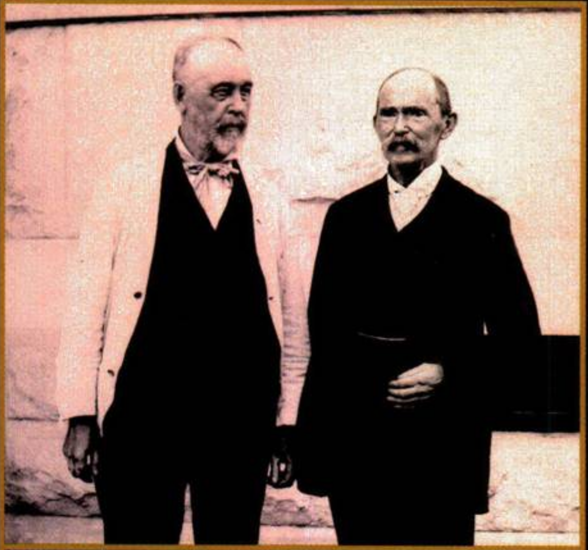
Why does Mars, more than any other planet, seem to demand so much of our attention? To me, the answer is simple: Apart from the Moon, Mars is the only world that shows us surface detail. The trackless pink deserts and darker martian "seas" are permanent features etched in stone. We gaze at real estate, honest "terra firma," and not just the top of a dense atmosphere.

The difficulty in observing Mars from Earth doesn't just affect backyard observers with small telescopes. Everyone must contend with a planet that never looms large and rarely grows beyond tiny. Physically, Mars has a diameter about twice that of the Moon, but it also lies much farther away. Even under the best of circumstances, it never strays closer than 140 times the Moon's average distance. That means in an Earth-based telescope, Mars can never appear larger than a 30-mile-wide (50-km-wide) lunar crater.

The eccentric orbit of Mars compounds the problem. Over the course of a 15- to 17-year cycle, Mars reaches opposition — its closest approach to Earth and the best time for observation — at different points in its path



THE PINK DESERTS OF MARS fired the imaginations of artists and scientists alike throughout the past several centuries. Here the Red Planet looms large over the boulder-strewn surface of its inner moon, Phobos. PAINTING BY CHESLEY BONESTELL/BONESTELL SPACE ART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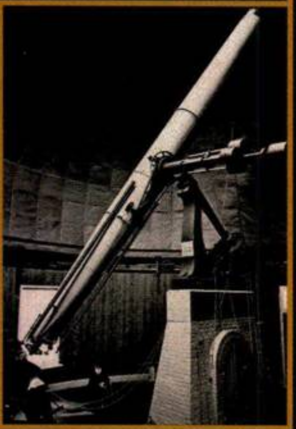
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ASTRONOMER ASAPH HALL and night assistant George Anderson (top; left to right) were the first two humans to see Phobos and Deimos, the moons of Mars. Here they are seen about 20 years after that momentous occasion. **THE LOGBOOK OF THE "GREAT EQUATORIAL"** (center) records observations of the moons on the night of August 18, 1877. A display case at the U.S. Naval Observatory contains the logbook as well as the Arago Medal of the French Academy of Sciences, the Gold Medal of the Royal Astronomical Society of Great Britain, and the Decoration of Chevalier of the French Legion of Honor, all awarded to Hall. **THE CRATER HALL** (bottom left) spans 3.5 miles (6 km) and lies near the south pole of Phobos. Interestingly, the largest crater on Phobos is named Stickney, after Hall's wife. **THE 26-INCH REFRACTOR** known as the "Great Equatorial" (bottom right) was installed in 1873. Here Simon Newcomb can be seen peering through the eyepiece.

around the Sun. As in 2003, the most favorable oppositions occur when Mars lies near perihelion, the closest point to the Sun in its orbit. Unfortunately, these oppositions occur when Mars is traversing the southern part of the ecliptic, so Northern Hemisphere observers have to look through more of Earth's atmosphere.

Undaunted, astronomers have gazed at Mars since the days of Galileo. The Italian astronomer saw little through his primitive telescope, but he thought he noticed a gibbous phase, an effect the heliocentric theory of Copernicus predicted. Another Italian, Francesco Fontana, thought Mars was a triangular rock with a black spot at its center, but Christiaan Huygens of the Netherlands was the first person to see a definitive feature on its surface. Observing the planet on November 28, 1659, he spied the region we now call Syrtis Major. The Italian-French scientist Giovanni Cassini gleaned enough surface detail to establish the planet's period of rotation and the tilt of its axis, both of which were remarkably similar to Earth's. These early astronomers had to contend with poor optics and restricted fields of view. As a result, few other significant observations of the Red Planet were made over the next century.

By the late 18th century, William Herschel in England and Johann Schröter in Germany turned their attention — and better telescopes — toward Mars. Schröter produced the first real maps of surface features, and both observers noted the form and seasonal variations of the polar caps. As improved telescopes became available to the skilled observers of the mid-19th century, the Mars familiar to most of today's amateurs began to emerge.

Scientific discovery

On a hot, hazy August evening in 1877, a bearded gentleman wearing a vested suit walked across the sodden lawn of the U.S. Naval Observatory grounds in the Foggy Bottom district of Washington, D.C. A summer thunderstorm had swept away the oppressive humidity for what the man knew would be only a few precious hours, offering clear skies and relative comfort for the task ahead. He entered the cavernous space of a large dome-topped room, and his gaze swept upward to fall upon the gleaming white tube of the world's largest refracting telescope.

"Good evening, Professor Hall," said a voice from somewhere in the darkness.

"Good evening to you, Mr. Anderson," came the reply.

The two gentlemen went about their business. George Anderson began the process of bringing the giant 26-inch "Great Equatorial" telescope to life: winding its driving clock, removing the cover over the precious objective lens, opening the dome slit, and rotating the dome into position so the telescope could aim at the sky. On one side of the room, Asaph Hall, Professor of Mathematics in the U.S. Navy Corps of Mathematicians, spread his notes out on the oak desk. He called out numbers from an almanac to Anderson, who duly pointed the telescope to the evening's target: a bright reddish object the Ancients had named for their god of war, Mars. Climbing into the observing chair, Hall was about to make one of the most important astronomical discoveries of the 19th century.

Geoff Chester *has been actively involved in amateur and professional astronomy for more than 40 years. He is currently the Public Affairs Officer for the U.S. Naval Observatory in Washington, D.C.*

Carefully focusing the eyepiece on the planet's blazing disk, Hall adjusted the great telescope so the glaring dot was just outside the field of view. Slowly sweeping the telescope around the circumference of the ruddy disk, his eye was caught by a star-like object that danced in and out of visibility in the glare of the brilliant limb. He had seen this object five nights earlier, just before clouds and fog from the nearby Potomac River had rolled in. Pausing for a few minutes, he noted the positions of Mars and the interloper with respect to the faint background stars. He soon noticed that the mystery object seemed to be moving along with the planet, but to be sure he needed confirmation from another set of eyes.

"Mr. Anderson, would you kindly come to the eyepiece and tell me what you see?"

"There appears to be a faint star near the planet, Professor."

"Is it moving with the planet, or with the stars?"

"I believe it's moving with the planet, Professor."

"Thank you, Mr. Anderson, that's what I thought. Please keep this to yourself until I inform Professor Newcomb and the others."

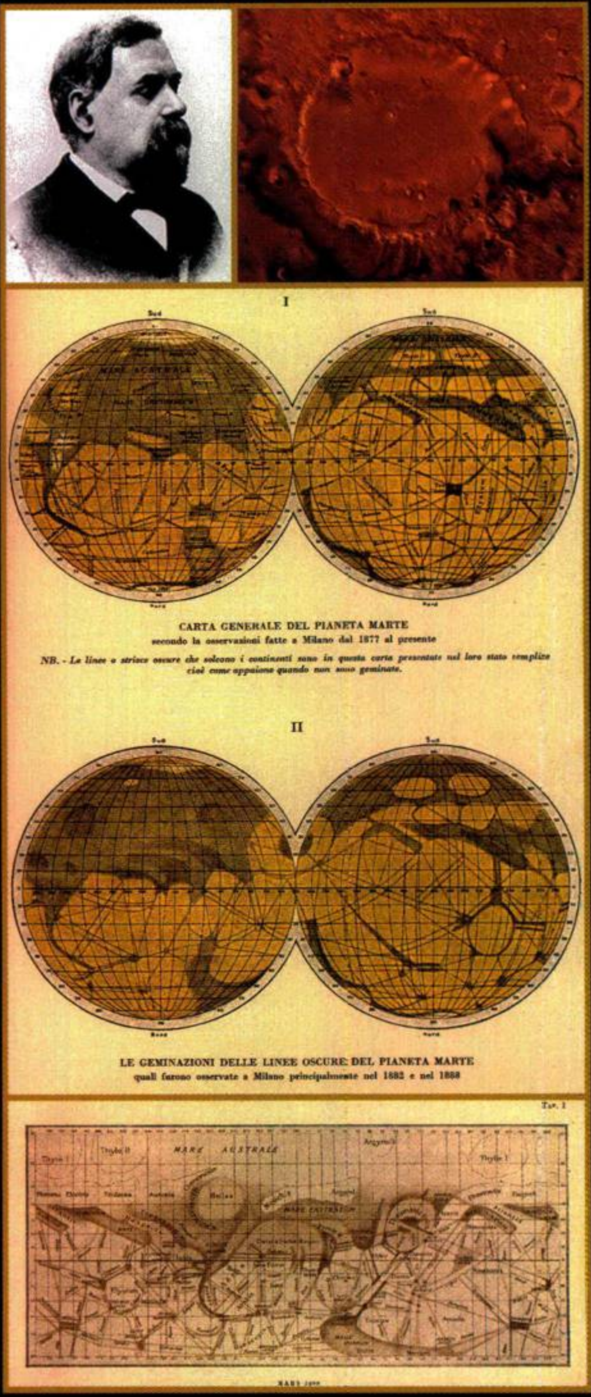
Later that same evening, the two men spied another, slightly brighter, object even closer to the planet's edge. They had seen the moons Phobos and Deimos for the very first time.

On the evening of August 18, a delegation of some of the most learned men in American astronomy gathered in the humidity of that great dome in Foggy Bottom. One by one they gazed through the eyepiece of the Great Equatorial at the faint "stars" hugging the limb of Mars. The last observer replaced the eyepiece with a filar micrometer, an instrument used to gauge precise positions, and began the laborious process of measuring the positions of the faint objects with respect to the center of the glaring martian disk. At last he called out a series of numbers, which Hall wrote in the telescope's observing logbook. At the bottom of the notation, he wrote a terse phrase: "Prof. Newcomb made the measures on this page."

In 1877, Mars had reached its most favorable opposition of the second half of the 19th century. Asaph Hall was ready. He had worked at the Observatory since 1862. When the Great Equatorial was installed in 1873, he was anxious to try his hand at working with it, but Simon Newcomb and his assistant, Edward S. Holden, virtually monopolized the great instrument for the next two years. Newcomb was interested in measuring double stars, so the giant telescope spent the few clear nights directed toward these objects. Newcomb eventually tired of the tedium involved in double-star measures and buried himself in more theoretical work, allowing Hall to work with the massive instrument.

During Saturn's opposition of 1876, Hall noted a small white spot on the planet's disk. He measured the spot's position dozens of times, deriving a rotation period for the planet that was 15 minutes faster than any previous estimate, and very close to the actual value. This achievement gave Hall the confidence to devote his next summer season to the study of Mars. Before starting his search, however, he chanced upon a number of photographs of the planet taken by Holden in 1875. The images were overexposed — Holden was clearly looking for moons.

Hall was also aware of earlier visual observations made by such noted observers as William Herschel, Johann Schröter, and Johann Encke, who swept the area around Mars to within a degree or so of its limb with no results. Doubtless, he knew as well of the fictitious


I
CARTA GENERALE DEL PIANETA MARTE
secondo la osservazioni fatte a Milano dal 1877 al presente
NB. - Le linee o striscie oscure che solcono i continenti sono in questa carta presentate nel loro stato semplice cioè come appaiono quando non sono geminate.
II
LE GEMINAZIONI DELLE LINEE OSCURE DEL PIANETA MARTE
quali furono osservate a Milano principalmente nel 1882 e nel 1888
Tav. I
MARE AUSTRALE
Thyle II
Thyle I
Argyre II

YERKES OBSERVATORY

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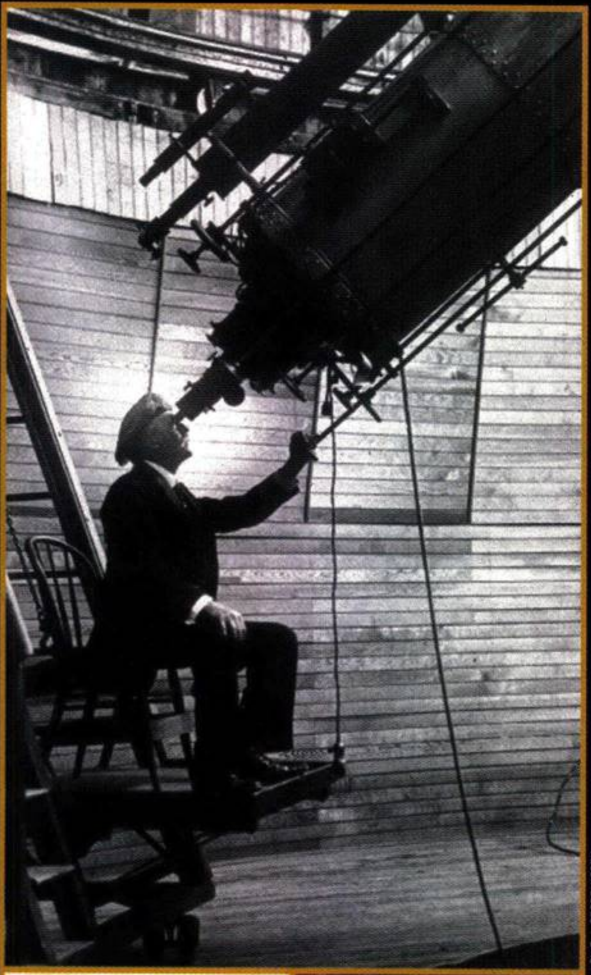
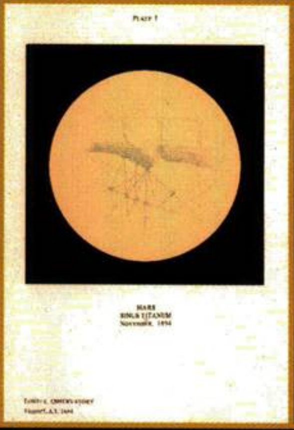
ITALIAN OBSERVER GIOVANNI SCHIAPARELLI [top left] detected faint linear streaks crossing the martian surface, launching a century of speculation about Mars and the possibility of life there. **THE CRATER SCHIAPARELLI** [top right] measures 293 miles [471 km] across, which fittingly makes it the largest crater on the planet's surface. **GLOBAL MAPS OF MARS,** painstakingly drawn by Schiaparelli from observations made during fleeting moments of good "seeing," clearly reveal the *canali* he thought he saw. The two sets of hemispherical maps [center] and the Mercator projection [bottom] show what may be Schiaparelli's most lasting legacy, however. For the most part, astronomers still use the names he coined for many of the bright and dark surface features. Look carefully and you'll see the giant Hellas basin, the prominent triangular wedge of Syrtis Major, the vast plain known as Elysium, and Tharsis, a region now known to harbor giant volcanoes.



LOWELL OBSERVATORY



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AMERICAN AMATEUR ASTRONOMER PERCIVAL LOWELL (top) spent years observing the Red Planet, building his own observatory in the clear mountain air of Flagstaff, Arizona, and trying to convince the public that Mars was inhabited. In this photograph, he's seen looking through the 24-inch refractor at Lowell Observatory. **TAKING CANALS TO THE LIMIT,** Lowell produced maps like this one (bottom left; the frontispiece from his 1895 book *Mars*) criss-crossed with what he viewed as advanced construction designed to bring fresh water to a thirsty populace. He observed regular seasonal variations, which he interpreted as agricultural activity, and darker waves that seemed to flow from the poles toward the equator. **THE DOUBLE-RINGED CRATER LOWELL** (bottom right) spans 126 miles (203 km) in Mars's southern hemisphere. In this image from the Mars Global Surveyor satellite, water frost covers the crater — a fact Lowell himself would no doubt appreciate.

feat of the Laputan astronomers in Jonathan Swift's *Gulliver's Travels* (Part III, Chapter III, written in 1726), who had discovered two moons of Mars through their far superior telescopes:

"They have likewise discovered two lesser Stars, or Satellites, which revolve about Mars; whereof the innermost is distant from the Center of the primary Planet exactly three of his Diameters, and the outermost five; the former revolves in the space of ten Hours, and the latter in Twenty-one and an Half; so that the Squares of their periodical Times, are very near in the same Proportion with the Cubes of their Distance from the Center of Mars; which evidently shews them to be governed by the same Law of Gravitation, that influences the other heavenly Bodies."

Hall thus eagerly anticipated the upcoming close approach of Mars. He hid his intentions from his colleagues, especially Holden, and waited for his rival to depart for a two-week visit to the private observatory of Henry Draper in New York. By the time Holden returned, claiming his own discovery of two more martian moons that were later discredited, Hall's historic achievement was secured.

The emergence of canals

Meanwhile, across the Atlantic Ocean, Mars was under scrutiny by one of the world's most celebrated observers. Giovanni Virginio Schiaparelli enjoyed the exclusive use of a fine 8.6-inch (22-cm) Merz refractor under the clear and stable skies of Milan, Italy. His interest lay more in the enigmatic surface of the planet, and he exhaustively measured the positions of hundreds of features to produce the first accurate map of Mars. His nomenclature system, which he used mainly for his own edification, became nearly universally adopted by the rest of the world's astronomers, a testament to his reputation as a scientist. Schiaparelli named the major features with evocative names derived from locations on Earth.

Although color-blind and nearsighted, Schiaparelli was gifted with extraordinary perception of faint, fine detail. In moments of steady "seeing," when Earth's atmosphere settled down and images became sharpest, he noted the sudden appearance of long linear streaks faintly crisscrossing the ocher deserts of the distant world. He announced to the world the existence of what he termed *canali*, the Italian word for "channel," which was subsequently misinterpreted as "canals." The combination of *canali* and other earthly feature names suddenly made Mars the closest thing to Earth's twin in the solar system. And for nearly the next 100 years, the idea of a planet inhabited by basic life-forms — and even races of hyper-evolved technological beings — held sway in the minds of the general public.

Controversy over the canals gained momentum through the end of the 19th century, fueled mainly by the observations of a wealthy Bostonian amateur astronomer, Percival Lowell, who plotted hundreds of long, delicate, perfectly linear streaks across the length and breadth of the planet. A few of the world's prominent astronomers embraced the idea that Lowell put forth: The canals were artificial structures built by a dying race of martian inhabitants. Many others remained skeptical of Lowell's claims, let alone his theories. Edward Emerson Barnard, considered by many to be the greatest visual observer of all time, never saw the canals, even when observing Mars with Lowell's 24-inch Clark refractor or the great 36-inch Lick and 40-inch Yerkes telescopes. Barnard, gifted with extraordinarily keen vision, instead saw sequences of dusky irregular features that, under typical seeing conditions, might give the impression of linear streaks.

Curiously, both Schiaparelli and Lowell noted that the canals were more prominent in smaller aperture instruments, or when Mars was far from opposition. Schiaparelli made most of his observations with the 8.6-inch Merz telescope, even though in later years he had a 19-inch refractor at his disposal; and Lowell habitually stopped the great 24-inch Clark down to 6 inches to offset the turbulence of Flagstaff's mountain climate.

Both Lowell and Schiaparelli went to their graves believing in the reality of canals. Indeed, a map of Mars made in 1896 by the eminent French astronomer E. M. Antoniadi showed a number of canals, although by 1924 he discounted their reality. And in the 1949 edition of *Challenge of the Stars*, the Bonestell images are carefully labeled: "Checked for color and 'canals' by D. Edison Pettit." In the end, it took the first images from a flyby spacecraft, Mariner 4 in 1965, to put the issue to rest.

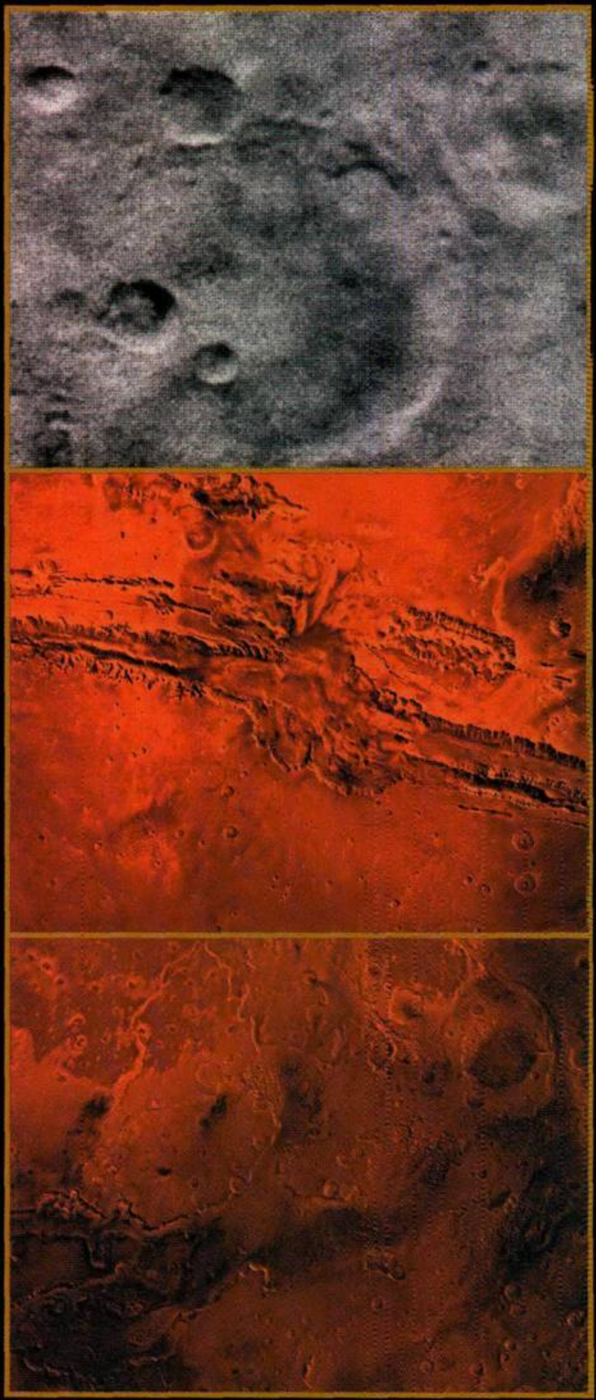
The impression of the canals, however, is a hard image to shake. I have glimpsed them on many occasions with the U.S. Naval Observatory's 12-inch Clark refractor in moments of steady air, but my impression of them mirrors Barnard's views. For split seconds the streaks resolve into a fine web of discrete, tiny, dusky patches that then seem to merge into linear features in more typical seeing. Attempting to record these features on paper defies most of our artistic abilities, but the impression stays in the back of the mind long after the planet has swung past opposition.

The 2003 apparition of Mars bears a remarkable geometric similarity to the historic 1877 event. Once again the planet will be greeted by legions of Earth-based observers, but this time they all will know far more about its distant ruddy shores than anyone before them. Yet they will still watch and wait for those fleeting moments when the tiny, dancing, pink dot in the eyepiece becomes momentarily still, revealing details that elude the skills of the finest draftsman.

We now know that Mars is a world with similarities to and differences from Earth and the Moon. It's about twice the size of the Moon and half the size of Earth. It has polar ice caps, volcanic mountains, a tenuous atmosphere that supports weather systems, and deep, water-cut channels; but its surface is scarred by impact craters comparable in size to those on the Moon. While we now routinely digest extraordinary close-up images of Mars beamed back from orbiting spacecraft, it's still remarkable to realize that a great deal of information was given up by the ocher deserts of that distant world to astronomers on Earth equipped with telescopes comparable to those available to today's amateurs.

The technology available to today's amateurs, however, would boggle the minds of the great visual observers of the past. It is now possible, with simple digital imaging devices, to capture detail on the surface of Mars limited only by the quality of the telescope's optics. The tiny details gleaned by hours of patient waiting at the eyepiece now can be captured in a matter of minutes and distributed almost instantly around the globe. This year, Mars will be under the greatest continuous scrutiny it has ever known. Who knows what surprises may be in store for those of us watching from a distance? ■

To learn what it's like viewing Mars with the U.S. Naval Observatory's 26-inch refractor, visit http://www.astronomy.com/toc



NASA/JPL

NASA/JPL

NASA/JPL

THE MARINER 4 SPACECRAFT returned the first close-up views of Mars when it flew less than 6,200 miles (9,900 km) above the planet in 1965. The images revealed a surface pocked with craters — and devoid of canals. A view of Mariner crater (top) typified what appeared to be a desolate planet. Subsequent spacecraft revealed a more dynamic world. **THE GIANT CANYON** known as Valles Marineris (center) stretches more than 1,800 miles (3,000 km) and averages 5 miles (8 km) deep, dwarfing Earth's own Grand Canyon. The vast, interconnected canyon system apparently formed by faulting and was later modified by landslides and erosion. Although water never flowed through canals as Lowell envisioned, water did flow on Mars's surface. **OUTFLOW CHANNELS** east of Valles Marineris (bottom) formed during catastrophic floods. They carried water northward from highland areas, draining into the Chryse basin off the top of this photo.

What is M
trying to h

Underneath its dry, barren facade, the Red Planet may host scorching lava, groaning glaciers, babbling brooks, and — dare we say it? — life. /// BY WILLIAM K. HARTMANN /// ILLUSTRATIONS BY ROEN KELLY

The pace of discovery in astronomy proceeds in fits and starts, seemingly advancing by giant leaps one moment and crawling to a standstill the next. Not until 1930 was tiny Pluto discovered at the far reaches of our solar system. But just a few decades later, astronomers were finding dozens of planets orbiting stars light-years away from the Sun.

And so it goes with Mars. Despite the reams of data from such missions as Mars Global Surveyor and Mars Odyssey, both currently orbiting the planet, the answer to the deepest question about our place in the cosmos — and the one that drives scientists to Mars — remains frustratingly out of reach. Do alien creatures or even intelligent civilizations exist elsewhere in the universe, or is life a special creation unique to Earth? Inquiring minds want to know whether a planet must be similar to Earth for life to spring up, and if so, whether early Mars was similar enough. It's a perfect question because either answer is profound. If life did sprout on the Red Planet, did it follow the same molecular course as on Earth? Did it die off, or could it be lurking somewhere beneath the rusty surface? If life never started there, does it mean we are more alone in the universe than we thought?

New discoveries raise the ante on such discussions of martian life. Using meteorites that have traveled to Earth from Mars over millions of years, observations from spacecraft, and computer models, scientists are closing in on the conditions that may have fostered biology on our dusty neighbor.

ars
ide?

THE TEMPERATURE OF EARLY MARS is up for debate between two broad theories. Intuition favors a warm model, in which Mars was temperate enough to melt some of the ice on and below its surface to form rivers. Pennsylvania State University geoscientist James Kasting has produced models in which abundant carbon dioxide and clouds in the early atmosphere trapped heat via the greenhouse effect, also responsible for Venus's higher-than-normal temperature.

Proponents of the alternative — a cold, wet, early Mars — point to the fact that the Sun emitted less radiation then than it does today, an effect, they say, that no amount of greenhouse insulation could overcome. And surprisingly, a colder early Mars may still explain the existence of rivers. A chillier climate would mean more ice on the planet in general, and more ice closer to the surface. Geothermal heat would have melted the subsurface ice, and floods of liquid water wouldn't have had far to travel to erupt above ground.

In fact, young planets have more short-lived radioactive isotopes that produce underground geothermal heat than do older planets. On early Mars, geothermal heating probably melted ice deeper than about one kilometer. In contrast, observations today suggest subsurface ice at middle to high latitudes may extend to depths of several kilometers.

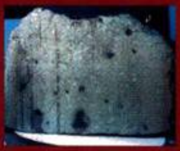
RECONSTRUCTING THE FINER DETAILS of martian history is an ongoing and controversial undertaking, but scientists believe the Red Planet went through three main eras — the Noachian, which lasted from 4.5 billion years ago until about 3.5 billion years ago; the Hesperian, which probably ended about 2 billion years ago; and the Amazonian, the current era.

The Noachian was a period of intense activity. The same types of small, rocky bodies that had formed the planets through successive collisions were still orbiting the Sun and frequently crashed into young Mars, forming craters. Vast outpourings of lava from volcanoes and fissures liberated large amounts of carbon dioxide and water vapor from within the planet, thickening the atmosphere, which researchers believe was a third or more of Earth's current pressure at sea level. (Today that figure is just one percent, too tenuous for liquid water to exist on most of the surface.) In the Noachian era (think Noah and his flood), water seems to have carved rivers, lakes, and oceans into the landscape.

[geology]

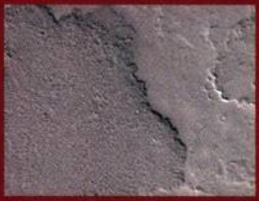
AFTER NASA'S VIKING MISSION TO MARS in the mid-1970s, some researchers believed that volcanism and water flow died out in the distant past — 2.5 billion years ago according to one popular chronology. But martian meteorites and photos from the Mars Global Surveyor spacecraft suggest Mars has been more active — more recently — than many people dreamed.

OF THE 28 MARTIAN METEORITES blasted from about six impact sites on Mars, all but one formed from lava and magma that crystallized on the Red Planet less than 1.3 billion years ago. In fact, one grouping of seven fragments from a martian lava flow is only 170 million years old, showing that lava has erupted on Mars within the last four percent of its history. Hot magma probably still exists, and martian volcanoes may erupt again at any time. Left: Meteorite EETA 79001 is one of the seven "young" fragments.



NASA

METEORITE RESULTS tie in beautifully with those obtained by a somewhat crude but important tool in the geologic dating game — scrutinizing craters. While scientists study crater sizes and other factors, simply counting craters provides a wealth of information about a surface's age. About 3 billion years ago, most impactors had struck planets, and the cratering rate diminished. So generally, the fewer the craters it has, the younger a surface is. Using data from Mariner 9 in the 1970s, my colleagues at the Planetary Science Institute and I counted craters on features such as Olympus Mons and the Tharsis plain. We found many martian lava flows with less than a tenth the crater density of the 3.6-billion-year-old lava plains on the Moon. Applying estimates that Mars gets roughly twice as many impacts per unit area as the Moon because Mars lies closer to the asteroid belt, we concluded that some lava flows were only a few hundred million years old. Left: Dark lava signals recent volcanism in the Tharsis desert. The box width represents 2.5 kilometers.



NASA/JPL/MALIN SPACE SCIENCE SYSTEMS

USING MARS GLOBAL SURVEYOR IMAGES to count craters as small as 10 meters across in volcanic areas such as Elysium Planitia (the box at left represents 4 square kilometers), Amazonis Planitia, and the slopes of Olympus Mons, Jen Grier, Melissa Lane, Dan Berman, and I have found many flows younger than 100 million years old, and some probably under 10 million years old.

NASA/JPL/MALIN SPACE SCIENCE SYSTEMS

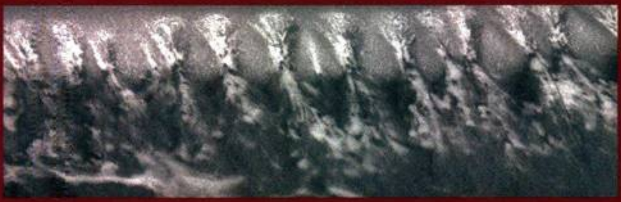
THESE YOUNG LAVAS imply that in certain places, magma may be moving under the crust in modern geologic times (within the last million years), heating the icy subsoil by tens of degrees. This could raise local underground temperatures from the average of –112° F to –40° F, the temperature at which salty water can stay liquid. In fact, Viking and Pathfinder landers found martian soils to be salt-rich, lending credence to theories of underground aquifers. These subsurface water tables could carry salt water through the ground and occasionally out onto the surface, perhaps explaining not only gullies and softened terrain, but "chaotic terrain," jumbled hills caused by the collapse of overlying surfaces.

[water]

THE IMPLICATIONS OF WATER ON MARS — in the past and especially in the present — are enormous, since life as we know it would be impossible on Earth without this simple molecule. So it would be wonderful if finding evidence of martian water was as easy as spotting the rings on a much-used bathtub. Luckily for us, it is. British researchers John Bridges, Monica Grady, and others have noticed that many martian meteorites contain deposits of salts and carbonates, the white material that forms bathtub rings when mineral-rich water evaporates. Left: The most striking such discovery involved a martian meteorite found in Indiana in 1931 — an igneous rock dubbed "Lafayette." Water had altered minerals in the meteorite, allowing scientists to date the rock's exposure to the liquid. After its formation 1.3 billion years ago, the rock sat for at least 630 million years until water seeped through it, proving that martian soil gets sporadic exposure to water.

NASA

IN 2000, Mars Global Surveyor camera builders Mike Malin and Ken Edgett spotted another feature suggestive of a watery past. At middle to high latitudes, they found many gullies running down from rocky outcrops on hilltops. On steep hills in Iceland, Greenland, and Canada, identical gullies form when water saturates the soil and causes it to flow downslope. The stunning aspect of the martian gullies is that they seem to prove widespread water release in recent times (some even have mud-like deposits at their lower ends). The big mystery is the source of the water — some researchers believe the height of the hills rules out leaky underground water tables as the cause, instead implicating melting subsurface ice. Below: At a southern latitude of 71°, frost glazes a hillside notched with gullies. No one knows whether the frost is tied to the gullies' formation.



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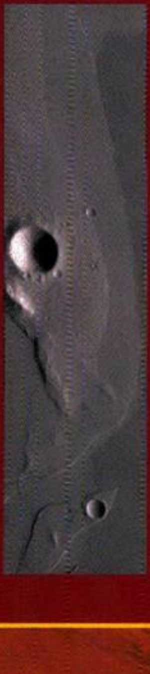


NASA/JPL/MALIN SPACE SCIENCE SYSTEMS

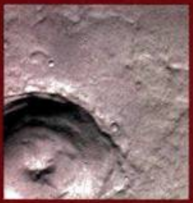
LARGE-SCALE EVIDENCE of ancient surface water began to pour in when Mariner 9, the first artificial satellite to orbit Mars, mapped what appeared to be dry riverbeds all over the frozen, arid planet in 1972. More controversially, researchers such as California Institute of Technology astronomer Tim Parker proposed that other features imaged by spacecraft are remnants of ancient lake beds, shorelines, and even ocean-filled basins. Most of these are pockmarked with craters, suggesting the bulk of water-related activity occurred in the first of Mars's three epochs then declined in the Hesperian era. But images from Mars Global Surveyor and radar topographic maps hint that water flowed recently on Mars. Arizona researchers Devon Burr, Alfred McEwen, Dan Berman, and others have analyzed a river-channel system called Marte Vallis that runs east from Elysium Planitia and north into Amazonis Planitia. With amazingly fresh features and few craters, the system may have hosted water within the last 40 million years. Left: A 140-square kilometer strip of the Marte Vallis channel reveals a water-eroded island (bottom) and a recent dark lava flow that has solidified with characteristic flow lobes (top).

[ice]

THE DISCOVERY OF ICE beneath the surface of Mars sheds light on a mystery called martian terrain softening. In ancient martian areas, crater rims often seem melted compared to similar features on the Moon, and local peaks are often surrounded by "debris aprons," which appear to have been caused by material that flowed like molasses off their slopes (left). These phenomena may be related to ice-rich soils that can flow like glaciers, a theory supported by the fact that softened terrain is more common at higher latitudes.

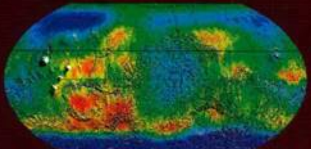
NASA

UNDERGROUND ICE was first suspected when Viking photos showed regions of hexagonal or rectilinear patterns on martian soil similar to those found in the Canadian tundra. There, the surface heaves and shifts into those designs when underlying ice freezes and thaws. Left: Some martian craters, like this one, which is about 12km wide, have petal-like ejecta patterns that seem to be caused by muddy slurry rather than dry dust and rocks. These rampart craters probably formed when impacts struck icy soil, melted the ice, and ejected mud.



THEMIS CAMERA/MARS ODYSSEY/NASA

IN 1980, researchers Ruslan Kuzmin and Joseph Boyce independently discovered that although rampart craters lie all over Mars, the smallest of them are smaller and shallower at higher latitudes. This means that closer to the poles, shallower craters tap into the ice, and measurements of crater depths bear this out — the permanent ice begins 300 to 400 meters underground at the equator, but less than 100 meters below the surface at high latitudes. In 2002, an international team of Mars Odyssey scientists discovered evidence of ice in the top two meters of the soil poleward of about 65° latitude. Below: Blue regions show hydrogen in the martian soil, an indicator of ice.

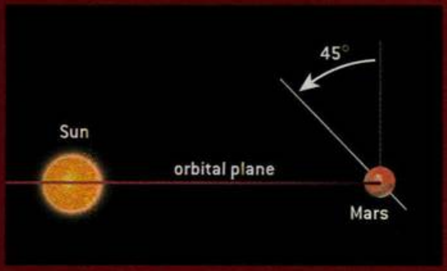


NASA/JPL/U. ARIZ./LOS ALAMOS NATIONAL LABS

MUCH OF THE FLOW apparently occurred in the ancient past, when water or ice may have been closer to the surface. However, certain Mars Global Surveyor photos show uncratered features that look like very young glacial flows (the region at left represents about 6 square kilometers) — another surprise to those who pictured Mars as dead. Computer simulations by Arizona researcher Elizabeth Turtle indicate that if ice is exposed on a slope, it could flow relatively quickly — within millennia, similar to glacial flows on Earth.

NASA/JPL/MALIN SPACE SCIENCE SYSTEMS

IN ADDITION TO WATER RELEASE by sporadic geothermal melting of ice, University of Paris astronomer François Costard and colleagues suggest another mechanism for recent ice activity. They believe that changes in Mars's axial tilt over cycles of a few million years may explain water- or ice-related features such as gullies. Unlike Earth, which leans at approximately the same angle due to the Moon's stabilizing gravitational pull, Mars is thought to go from an upright position to a deep bow of 45° over 5 million years or so (below). As one polar cap tips more toward the Sun, the additional heat releases ice and carbon dioxide trapped in the ground. This could raise the atmospheric water vapor content enough to condense ice or drop snow onto the surface during winter. Costard believes the orientation of the gullies, most of which face the poles, can be explained by melting ice on poleward-facing slopes. Warmed by both a daytime and a midnight Sun, these receive more sunlight than other locations when the planet is listing heavily toward our star.



ASTRONOMY: ROEN KELLY

[life?]

THE EXISTENCE OF WATER AND ICE on Mars excites researchers hopeful of one day finding life there, but some people believe we've already found it. In 1996, a NASA team headed by D. S. McKay and Everett Gibson stunned the scientific world by announcing possible fossil microbes (below) in water-deposited carbonates inside the one martian meteorite that dates back 4.5 billion years, when the martian crust was forming.

The jury is still out on that controversial proposal, but in 2000, biologists Russell Vreeland and William Rosenzweig and geologist Dennis Powers reported viable bacteria inside 250-million-year-old salt crystals from Earth. Their discovery inside the crystals suggests the bacteria were indeed as ancient as their salty tombs and heartens Mars researchers who know that life would have to be similarly hardy to survive the Red Planet's harsh conditions.

It's too early to say whether life exists on Mars today or has in the past. Yet recent observations have painted a planet with abundant water, ice, and volcanic energy, opening pathways to future discovery over how life might evolve and maintain itself on a planet that is at once so alien and so familiar.

NASA

William K. Hartmann *is a member of the Mars Global Surveyor imaging team and a senior scientist at the Planetary Science Institute in Tucson, Arizona. This article is adapted from his new book,* A Traveler's Guide to Mars.

Learn more about martian geology, history, and meteorites at http://www.astronomy.com/toc.

{ MARTIAN EXPLORATION }

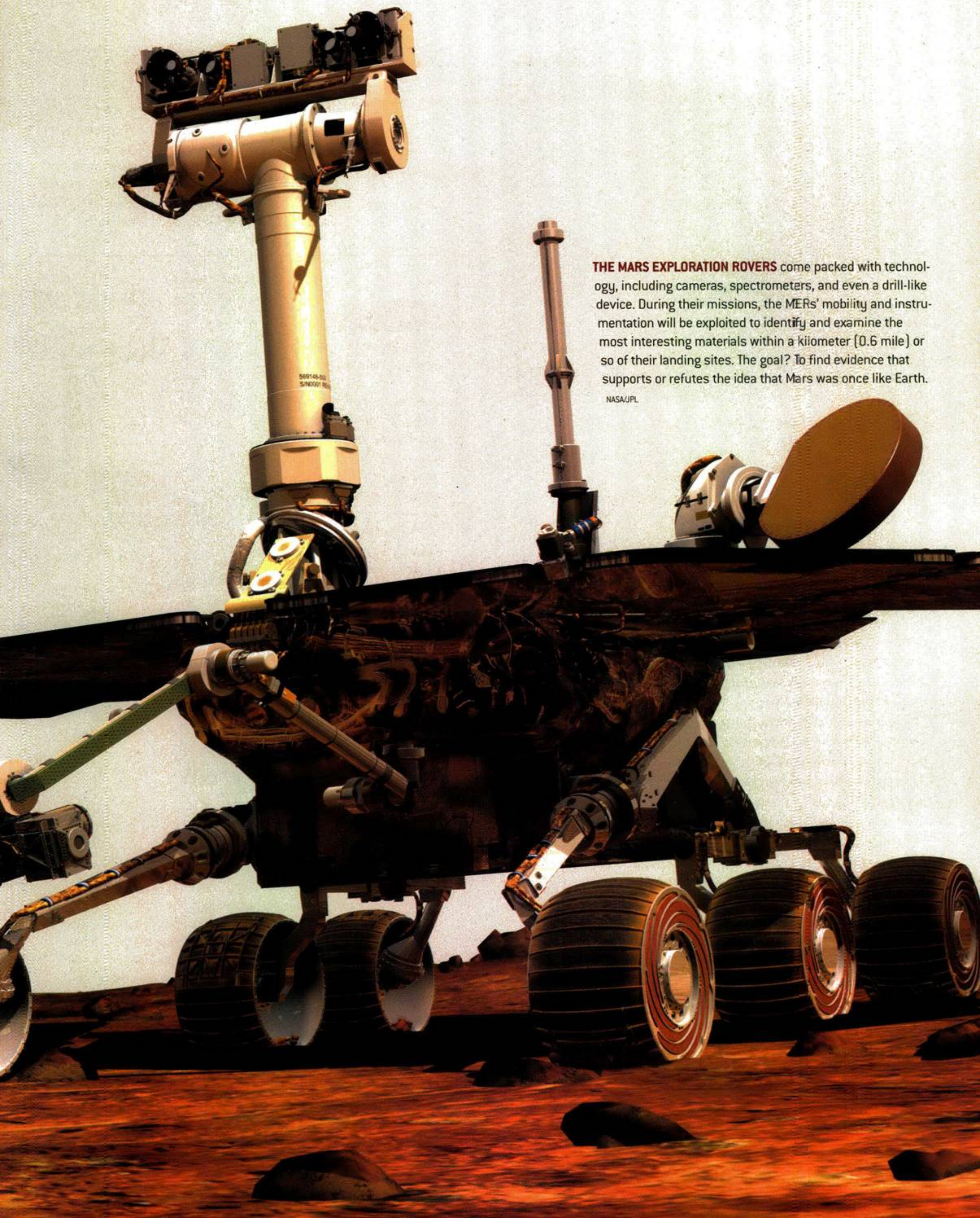
Blazing a new path

Two new rovers will follow in Pathfinder's track marks, wandering the martian surface in search of proof that Mars once did (or did not) support life. /// BY JIM BELL

Imagine being asked to lead an expedition to an uncharted corner of a world on a mission to discover that place's history. How would you do it? You might assemble a team of brave and hardy experts with field experience in geology, biology, climatology, and maybe even anthropology. You'd need tools, a power source, and provisions for the team. Once there, you'd also need mobility. And you'd need a way to communicate — to share information and to tap into expertise back home. Overall, it would be a complex and expensive exercise merging aspects of science, technology, engineering, management, and human psychology to achieve a single goal: to learn.

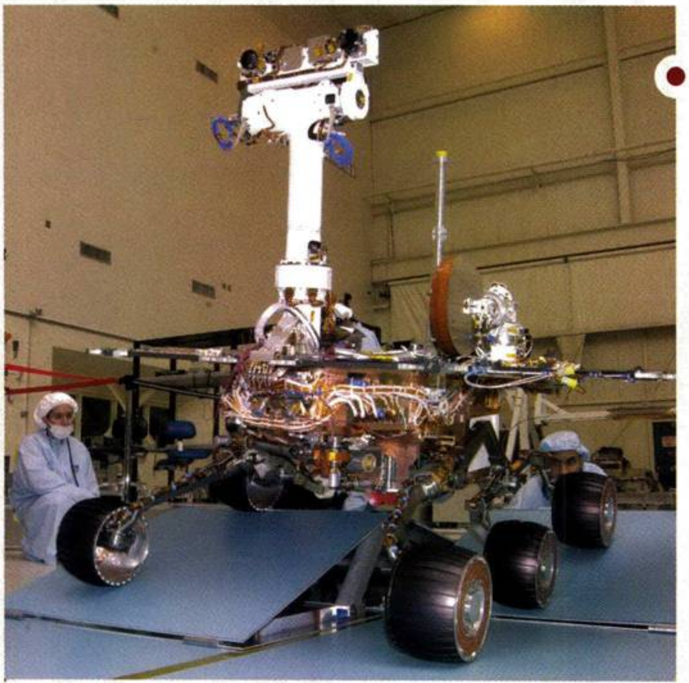
Welcome to Mars exploration.

Human fascination with the Red Planet goes back generations, but it's only in the last few decades that we have been able to reach out and touch the place. The Mariner and Viking missions provided initial reconnaissance of Mars, revealing a planet of paradoxes. More questions and stunning discoveries came from the recent Mars Global Surveyor, Pathfinder, and Odyssey missions. While details are still being worked out, one thing is clear: Ancient Mars was unlike modern Mars. Was it more like Earth? If so, for how long? Could life have taken hold? If so, does it persist anywhere on Mars? These questions drive current Mars exploration, and answering them is the goal of the Mars Exploration Rovers mission.



THE MARS EXPLORATION ROVERS come packed with technology, including cameras, spectrometers, and even a drill-like device. During their missions, the MERs' mobility and instrumentation will be exploited to identify and examine the most interesting materials within a kilometer (0.6 mile) or so of their landing sites. The goal? To find evidence that supports or refutes the idea that Mars was once like Earth.

NASA/JPL



SCIENTISTS TEST-DROVE ROVERS over obstacles to make sure they could hold up on rough terrain. NASA/JPL

The big question: biology

The martian surface is a hostile place for man and machine. The surface atmospheric pressure is 1% of Earth's, and nighttime temperatures can drop to –112° F (–80° C) or lower. It's bone dry — if all the water in the atmosphere were condensed into liquid and spread across the planet, it would be only a few tens of microns thick (Earth's would be meters thick). As far as we can tell, the surface is sterile. Organic material in various soils tested by the Viking landers was at the parts-per-billion level or lower. At first glance, today's Mars has an environment hostile to life as we know it.

But additional data suggest things were not always this hostile. Mariner and Viking orbiters imaged enormous volcanoes, large tectonically-formed canyon systems, and complex and dynamic polar caps composed of both water and dry ice. These structures demonstrate that different geologic and climatic processes — perhaps involving water and a warmer climate — acted in the past.

Perhaps most surprisingly, images show long, deep channels. Modeling and comparison to channels on Earth suggest the channels were formed by liquid water. Other measurements — images of possible flood-related features, the detection of water-bearing or water-formed minerals, and evidence for atmospheric loss over time — all point to a past when Mars was once wetter.

These interpretations are controversial, however, and they frame one of the most important debates in the planetary science community. Was Mars really once earthlike geologically, climatically, and maybe even biologically? Or are we being fooled by a wishful interpretation of the data? The question is big and the implications are profound; it is scientific only if we test it as a hypothesis through careful observations and measurements.

Jim Bell *is a planetary scientist in the Department of Astronomy at Cornell University in Ithaca, New York. He is the lead MER science team member responsible for the rovers' Pancam instrument and has a wicked table tennis serve.*

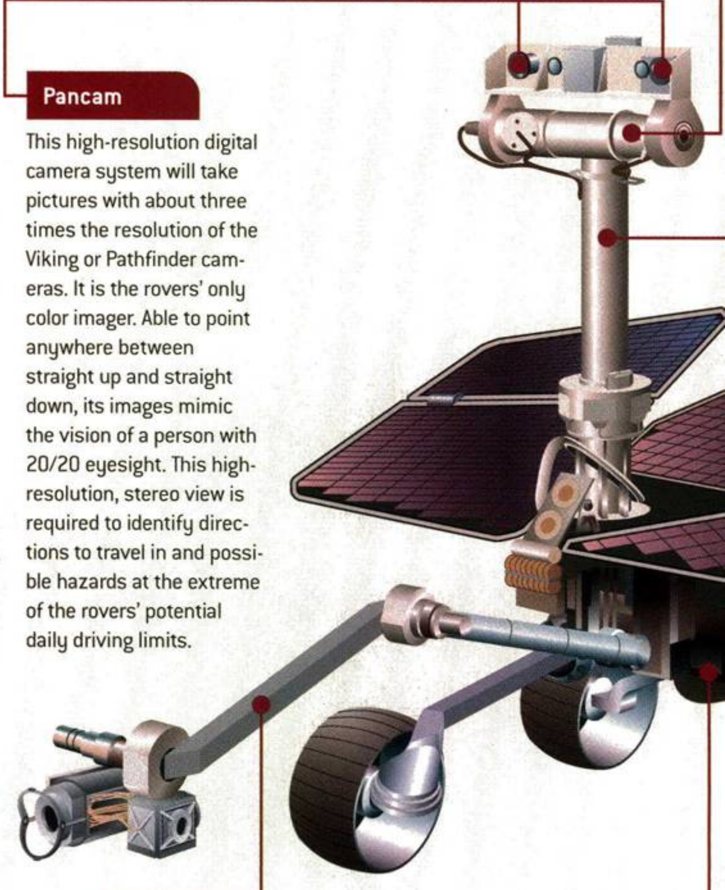
Inside the new Mars rovers

Mini-TES

This infrared spectrometer measures heat from rocks, soils, and the sky and disperses that heat-energy into spectra that are used to identify composition. Mini-TES is a smaller version of the TES instrument on Mars Global Surveyor. Reflectors beneath the Pancam send light to the instrument at the mast's base. Mini-TES will play a big role in looking for evidence of water.

Pancam

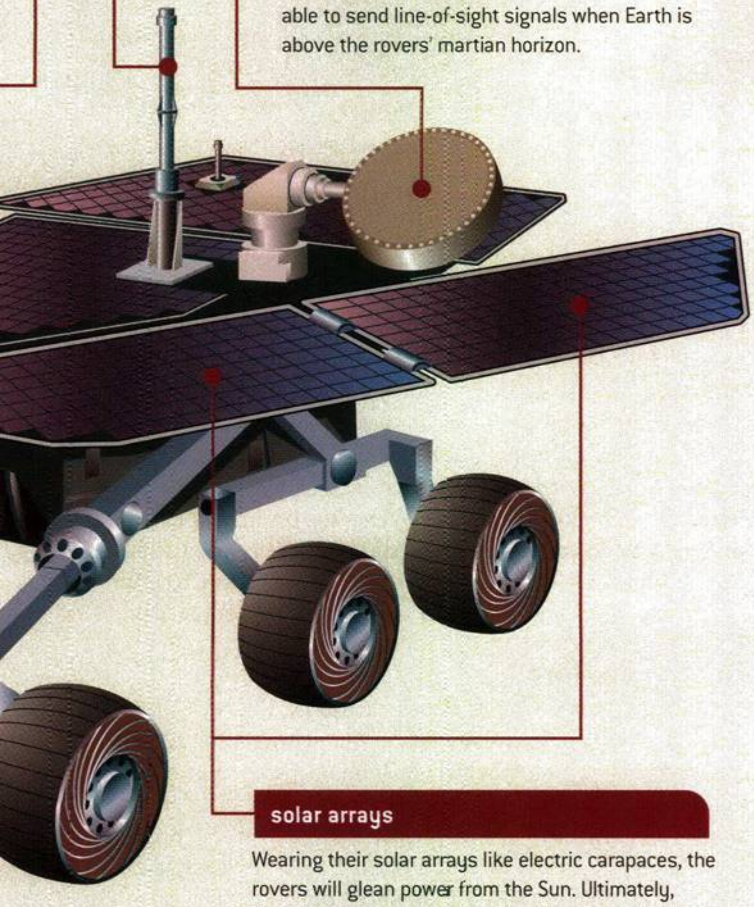
This high-resolution digital camera system will take pictures with about three times the resolution of the Viking or Pathfinder cameras. It is the rovers' only color imager. Able to point anywhere between straight up and straight down, its images mimic the vision of a person with 20/20 eyesight. This high-resolution, stereo view is required to identify directions to travel in and possible hazards at the extreme of the rovers' potential daily driving limits.



arm

The arm has about the same length and agility as a human arm, and its four instruments can be positioned accurately onto rocks or soils or onto specially designed calibration targets on the rovers themselves. The instruments include an imager, two spectrometers, and a drill-like device. Its Microscopic Imager takes digital images of rocks or soils with hand-lens scale detail (about 30 microns per pixel). The Alpha Particle X-ray Spectrometer, which is similar to Sojourner's spectrometer, will measure the elemental surface chemistry. A Mössbauer spectrometer can accurately identify certain iron-bearing rocks and minerals. The arm's small, drill-like Rock Abrasion Tool can dig a few centimeters into rocks to expose clean, unweathered surfaces that can be measured by the other arm instruments.

ASTRONOMY: JAY SMITH



mast

A deployable mast extends to approximately 59 inches (1.5 meters) above the rovers. Home to Pancam and Mini-TES, this mast can rotate each instrument a full 360°.

low-gain antenna

This low-gain antenna may be able to use Mars Global Surveyor or Mars Odyssey orbiters to relay messages to Earth. As a backup system, it can also contact Earth directly, albeit slowly.

high-gain antenna

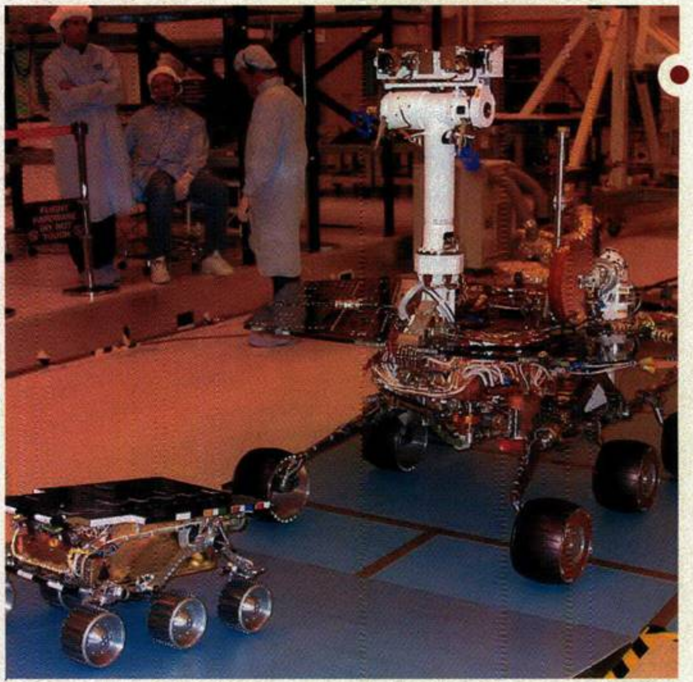
The MERs' primary communications link to Earth is through this high-gain antenna. It will only be able to send line-of-sight signals when Earth is above the rovers' martian horizon.

solar arrays

Wearing their solar arrays like electric carapaces, the rovers will glean power from the Sun. Ultimately, their lifespan may be determined by how quickly dust builds up on their solar arrays, preventing the MERs' batteries from efficiently recharging.

hazard avoidance cameras (Hazcam)

Located at the front and rear of the rovers, the four black-and-white Hazcams will provide up-close images of the rocks and soils the rovers traverse, while looking for things the rovers shouldn't try to cross or climb over.



ROVER MEETS ROVER in this family portrait of a Mars Exploration Rover and the backup rover for Pathfinder, Marie Curie. NASA/JPL

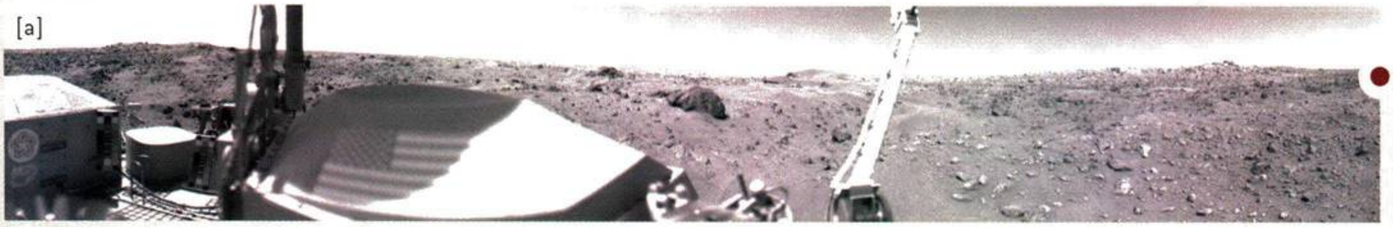
Those of us working on the Mars Exploration Rovers (MERs), for which I'm a lead scientist, are taking this approach: With our two highly-mobile and well instrumented rovers, we will study the climatic and geologic histories, as well as the history of water in two landing sites, Gusev Crater and Meridiani Planum. The primary goal of this mission is to better understand the evolution of places where conditions may be favorable for preserving evidence of life and pre-life processes. We are seeking evidence to support or argue the hypothesis that in the past Mars was more like Earth.

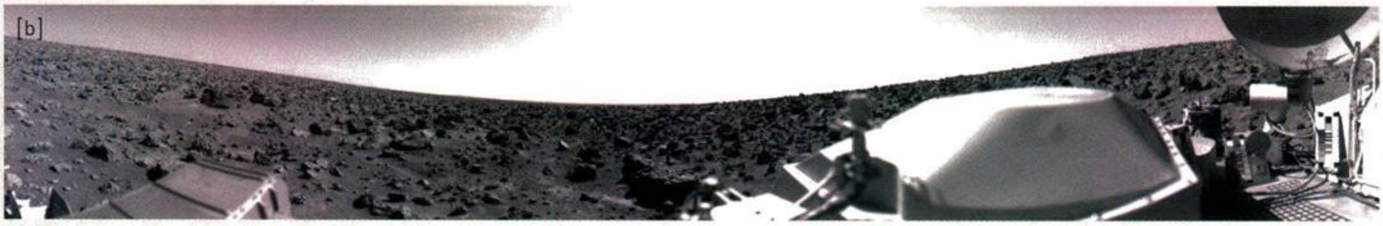
Mission history

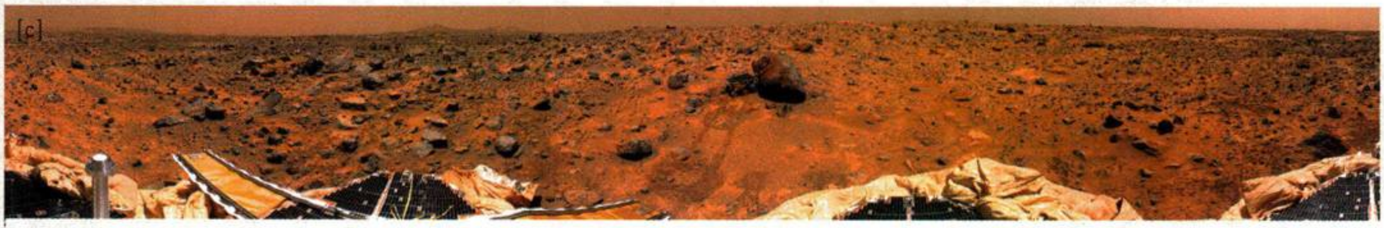
The scientific experiments the MERs carry were conceived in the mid-1990s to obtain measurements to clearly define Mars's climate and geology. Information from the rovers, when coupled with extensive imaging during landing and from orbiting spacecraft, will provide a big-picture understanding of the landing sites.

The MER instrument payload was first proposed to NASA as part of the Mars Pathfinder mission, but it was not selected. After several resubmissions of our idea, the MER payload was given a green light in 2001. Unfortunately, budget cuts and the 1999 loss of both the Mars Polar Lander and Mars Climate Orbiter led to the cancellation of the 2001 landing mission. This was actually to our advantage because NASA decided to send twin rovers with the payload we had proposed on a 2003 mission to Mars. Our work doubled instantly, but so did the potential for discovery.

Most of the actual assembly of the rovers and instruments took place during 2002, and an extensive testing program ran from mid-2002 through early 2003. Starting with individual components, our testing culminated in test-drives of the full rovers and other critical systems in a simulated martian environment. While testing done on Earth can never reproduce all the conditions expected on Mars — the lower gravity, the degree of dustiness, and the specific weather conditions at the time of landing can all only be modeled — the program has been as extensive as possible.







[a] **VIKING 1 OPENED A WHOLE NEW WORLD** for unmanned human exploration when it landed on Mars on June 19, 1976. NASA/JPL

[b] **VIKING 2 TOOK UP STATION ON MARS** on August 7, 1976, becoming the second NASA lander to claim part of the Red Planet. NASA/JPL

[c] **SOJOURNER EXPLORED MARS'S SURFACE,** testing new technologies as it paved the way for later rovers. It landed on July 4, 1997. NASA/JPL

The payload

Each rover carries an impressive suite of instruments that can be broadly grouped into three categories: remote-sensing science, up-close science, and mission operations or "engineering" support. To maximize the efficient use of power and other critical resources, many instruments perform functions in more than one category.

The primary, remote-sensing science instruments are a stereo panoramic camera system called Pancam and a miniature thermal emission spectrometer called Mini-TES. Pancam will be our team's eyes, replicating the resolution and stereo-view of a human standing on Mars. Through our robot, we will see the surface of Mars with unprecedented clarity. Like human vision, Pancam will be used to learn, to navigate, and to avoid obstacles.

Mini-TES is based on the already successful TES on the Mars Global Surveyor. TES observed volcanic minerals, placed strong upper limits on the abundance of carbonates and other potential mineral "sinks" of past atmospheric gases, and discovered places where the planet's ubiquitous iron oxides may have unusually large grains. One of these places is the MER landing site Meridiani Planum. It is hypothesized that these larger-grained minerals formed in a water-rich environment, and we are sending Mini-TES to confirm if these grains are minerals indicative of water. By comparing its results with TES, Mini-TES will test the ability of remote-sensing satellites to predict accurately the kinds of materials found on the surface of Mars.

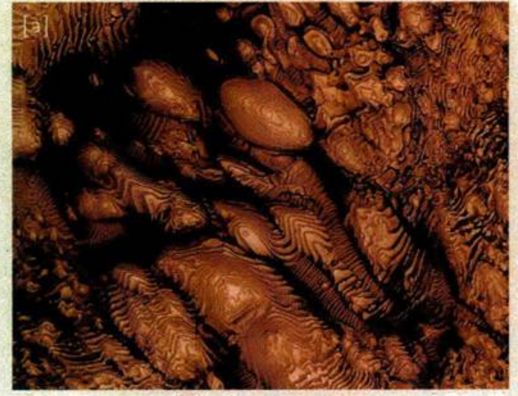
The MER payloads are quite synergistic, with many instruments serving multiple functions. The Hazcam (Hazard camera) images, for instance, will provide close-up views of the texture of soils, rocks, and pebbles, while Navcam (Navigation camera) images will identify potential regions for high-resolution Pancam imaging or arm instrument work. Even before it sets wheel on Mars, the landing structure for the MERs will be looking for directions to explore while providing for a safe descent by taking images of the landing site with a black-and-white digital camera. The rovers' wheels will even conduct scientific investigations, such as measuring the properties of the surface soil deposits and exposing the shallow subsurface during dedicated trenching activities.

Some of the science instruments also will be used for support tasks. For example, Pancam will serve as the rovers' primary Sun-finding camera. In this role, it will track the rovers orientations and headings. Together, the instruments on MERs will keep the rovers safe while acquiring a broad spectrum of scientific data.

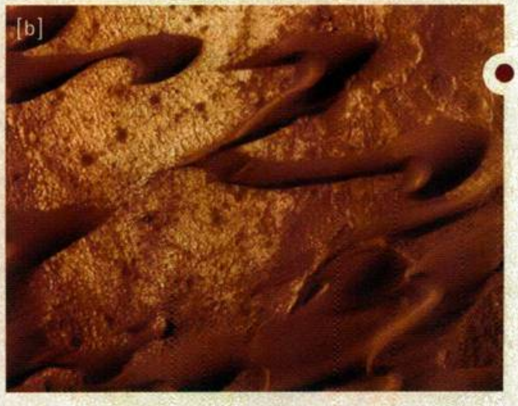
Driving on Mars

Operating a remote-controlled vehicle from a distance of 100 million miles (170 million kilometers) or more is a complex task that involves an enormous amount of planning and cooperation among many groups. One common misconception is that controllers on Earth are actually "joysticking" the rovers — driving them in real time from place to place on Mars. However, it really doesn't work that way. Even at the speed of light it takes radio signals from 20 to 30 minutes to travel to the rovers and back. In addition, Mars's rotation will carry the rovers out of direct, line-of-site contact with Earth for nearly 12 hours each day. And finally, only a small number of large radio antennae, like those in NASA's Deep Space Network, are capable of receiving the faint signals of interplanetary spacecraft (and of transmitting enough power to send signals back to them).

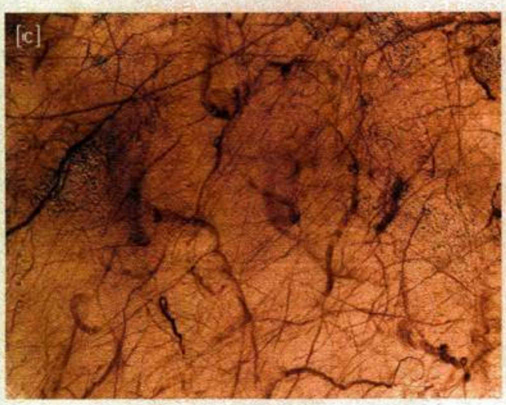
The rovers will actually operate autonomously, using hardware and software designed to make intelligent and safe decisions about where to drive and how to obtain scientific measurements. About once a day, we will send each rover a series of orders for the next



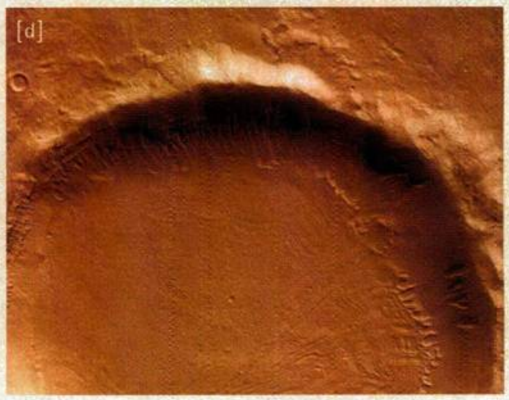
[a] **DEEP IN THE HEART** of West Arabia Terra Crater, layers of sediment are exposed by erosion. The sediments either settled out of the atmosphere to build up these deposits, or perhaps they settled out of water that may once have filled this crater. MOC M14-01647 NASA/JPL/MSSS



[b] **DUNES FLOW ACROSS** the Nili Patera region of Syrtis Major. A constant wind from the upper right of this image has swept dark sands steadily across this region. MOC 2-88 NASA/JPL/MSSS



[c] **DUST DEVILS DANCE** twisted trails across the Promethei Terra region of Mars. These dark streaks form when dust devils remove bright dust from an otherwise dark surface. MOC 2-220-B NASA/JPL/MSSS



[d] **ELDER CRATERS** show weathering and erosion. Cut into the side of this crater are gullies that were likely formed by melting water from remnant snow packs. NASA/JPL/ASU

day's activities. Commands might be something like: "Wake up at 0900 tomorrow. Once solar panel power levels are high enough, power on the Pancam cameras and let them warm up. Find the Sun and verify heading. Take a 180° color panorama toward the north. Drive 25 meters on heading 10°, turn 90° right, and drive 3 meters forward to approach next target rock." We will also receive a downlink from the rovers containing all of the previous day's science data and engineering telemetry.

Each rover's primary communications relay is a high-gain antenna pointed directly at Earth. If this fails, backup systems exist, including a low-gain antenna for slower direct-to-Earth communications and a UHF antenna for indirect communications to Earth via radio contact with the Mars Global Surveyor or Mars Odyssey orbiters. These orbiters will serve as the first martian communications satellites for a surface mission. Getting the rovers' uplink to the orbiters working is important not only as a backup for the communication system but also as a way of doubling, or perhaps tripling, the amount of imaging data returned to Earth.

The first rover is scheduled to land on January 4, 2004, with the second following three weeks later, on January 25. Each rover is designed to operate for at least 90 martian days, or sols. A sol is about 37 minutes longer than an Earth day, so team members operating the rovers from Earth will slowly alter their schedules by about a half hour per day to keep in sync with martian time.

If the rovers are still operating after 90 sols, we will propose to extend the mission for as long as possible. Ultimately, the rovers' lifetimes will be determined either by the limited number of charge/discharge cycles that the batteries can handle or by the power drop that will come with the slow accumulation of dust on the solar panels. Death may also result from the failure of some component stressed by the low temperatures of the martian night.

Future expectations

Missions like MER are part of a larger, long-term, international strategy for Mars exploration. The European Space Agency's Mars Express orbiter was launched in June 2003. It will obtain data on Mars's geology and composition, and it will deploy a small, stationary lander named Beagle 2 for additional physical and chemical studies. Japan's Nozomi orbiter, arriving at Mars in 2004, will study the planet's upper atmosphere. In 2005, NASA will launch the Mars Reconnaissance Orbiter to obtain even higher resolution views of the surface and to monitor Mars's climate. Plans beyond this are still forming, but possibilities include science or telecommunications orbiters, a rover carrying a chemistry/biology lab (2009), and a Mars sample return mission (2011 or 2013).

These robotic missions provide crucial information necessary to support what may be the next logical step — human missions to Mars. While no agency has formal plans for manned missions, many of the necessary technologies are under investigation. Current and planned robotic missions, both orbital and landed, are obtaining the data needed to design manned missions. Human exploration of Mars will be more expensive than robotic exploration but not more expensive than many other nationally and internationally funded programs and enterprises. Manned missions to Mars will be risky, but there is no shortage of people willing to face these risks to make one of the most inspirational and educational voyages of exploration attempted in our time. If we can muster the will and buttress it with knowledge and technical expertise gleaned from exciting robotic precursor missions like the MER, Mars is within our grasp. ■

To see the MERs and their prototypes being put to the test before a live laboratory audience, visit http://www.astronomy.com/toc

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ACCESSORIES

New!

Orion V-Block™ Anti-Fringing Filter

The Orion V-Block filter effectively removes distracting color halos from around bright objects, greatly improving image sharpness, color, contract, and resolution. Works well with achromatic refractors of any aperture or focal length. Threads into eyepieces, diagonals, and barlow lenses that accept 1.25" or 2" filters.

1.25" V-Block Filter	**$69.95**
2" V-Block Filter	**$89.95**

Orion® Color Planetary Filter Sets

Color filters allow you to see more detail when viewing the planets or Moon. Made from high-grade Hoya optical glass, each Orion filter is vat-dyed to even color distribution and fully antireflection coated.

Basic Set of Four Filters (#15 Deep Yellow, #25 Red, #58 Green, and #80A Medium Blue)

1.25" $39.95 2" $74.95

Expansion Set of Four Filters (#11 Yellow-Green, #21 Orange, #47 Violet, and #82A Pale Blue)

1.25" $44.95

Advanced Set of Four Filters (#8 Light Yellow, #23A Light Red, #38A Deep Blue, and #56 Light Green)

1.25" $44.95

New!

Orion LaserMate™ Deluxe Laser Collimator

The LaserMate Deluxe Collimator makes collimation a simple, one-step procedure. A "rear view" port in the aluminum housing lets you see both the emitted and return beams while standing at the rear of the telescope. Just tweak the collimation bolts until the beams overlap for laser-precise collimation at lightning speed. Ideal for any reflector. Fits any 1.25" eyepiece holder. Just 5 3/4" long.

DANGER
LASER RADIATION

$79.95

Padded Scope Cases

Protect your investment with a padded, polyester/nylon case. Strap handles for easy carrying. Many sizes.

From **$24.95**

SteadyPix™ Universal Camera Mount

This nifty device couples any digital or film camera to the eyepiece of any telescope for through-the-eyepiece photography. Attaches directly to any standard 1.25" telescope eyepiece. Camera threads on to a 1/4"-20 pedestal via the threaded hole in the camera body.

$34.95

Deluxe Aluminum Accessory Cases

Three different sized aluminum-clad accessory cases with pre-cut foam compartments, make it easy to organize and protect eyepieces, barlows, filters and other valuable accessories.

Sm **$22.95** Med **$32.95** Lg **$42.95**

Atlas™ Heavy-Duty Equatorial Mount

Our beefiest and most advanced mount offers amateur astronomers a rock-stable platform at a price unheard of before. Supports telescope tubes of up to 40 lbs. Atlas comes with dual internal DC stepper motor drives, 3" setting circles, polar alignment scope, 2" stainless-steel tube legs, and two 11 lbs. counterweights. Weight (without counterweights) 54 lbs.

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Sale!
SAVE $13

Orion Shorty-Plus™ 3-Element 2x Barlow Lens

Our Shorty-Plus 2x Barlow is the highest-quality, most versatile barlow you'll ever own. All optical surfaces are fully multi-coated for maximum light transmission and contrast. Just 2 3/4" long. Accepts 1.25" eyepieces of diagonal. Made in Japan.

Was $69.95 NOW $56.95

Shorty™ 2x Barlow Lens

This compact barlow is just 2-7/8" long, about half the length of a regular barlow, for greater convenience and versatility. Fits all 1.25" telescope eyepieces. Features a multi-coated, baffled achromatic lens system.

$39.95

RockStable™ Anti-Vibration Pads

Special visco-elastic material reduces vibrations from wind and other sources. Ideal for both visual astronomy and astrophotography. Sold in sets of three.

$48.95

EYEPIECES

Orion® Electronic Imaging Eyepieces

View real-time images from your telescope on a T.V. set! Each unit contains a CCD detector similar to the chip in a video camcorder (1/4"-square CCD chip with a 320x240 pixel array in the monochrome eyepiece and a 1/3"-square CCD chip with a 640x480 pixel array in the color eyepiece). Each includes a 9-volt alkaline battery and RCA cable.

MONOCHROME
COLOR
New!

Monochrome Electronic Eyepiece	**$64.95**
Color Electronic Eyepiece	**$119**

Expanse™ Wide-Field Eyepieces

With their 66° apparent field of view, our Expanse wide-field eyepieces will definitely turn up the Wow! factor in your deep-sky observing experiences! Imagine taking in objects like the Andromeda Galaxy, the Double Cluster, or the star clouds in Sagittarius in one sweep! With an Expanse in your focuser, you can! Fully coated, rubber eyeguards.

6mm, 9mm, 15mm, 20mm **$49.95**

Sirius™ Plössl Eyepieces

You could pay twice the price for other brands of Plössl eyepieces, but why? Sirius Plössls are top-quality, 50° apparent-field (43° 40mm) eyepieces that yield extremely sharp images of impressively high contrast. Ideal for all types of telescopes. Fully-coated optics, rubber eyeguards.

1.25"

6.3mm, 7.5mm, 10mm, 12.5mm, 17mm, 20mm, 26mm	**$39.95 each**
32mm, 40mm	**$44.95 each**

Epic™ ED-2 Eyepieces

Our new ED-2 eyepieces are made of "Extra-low Dispersion" optical glass that boasts superior refractive properties. Epic 1.25" eyepieces feature a six-element lens design in which two of the elements are crafted from ED glass. Each provides luxurious 20mm eye relief, reduced chromatic aberration and a wide 55° apparent field.

25mm, 22mm, 18mm, 14mm, 12.3mm, 9.5mm, 7.5, 5.1mm, 3.7mm

$69 ea.

BINOCULARS

Orion Savannah™ Phase-Coated Binoculars

Our Savannah roof prism binoculars are the binoculars of choice for anyone wanting a premium-quality field glass. Now, Savannah's phase-coated optics ensure lockstep light paths for enhanced contrast and resolving power. And, they're waterproof!

8x42 Savannah	**$299**
10x50 Savannah	**$319**

Orion UltraView™ Binoculars

UltraView binoculars combine fabulous light-gathering capability with long eye relief and unsurpassed optical performance.. With BAK-4 glass prisms, fully multi-coated eyepiece and objective lenses and precision-engineered cast-metal alloy body.

8x42 Wide-Angle UltraView	**$149**
7x50 UltraView	**$169**
10x50 Wide-Angle UltraView	**$169**

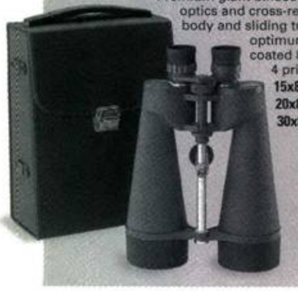
FULLY MULTI-COATED OPTICS!

Vista™ 50mm

Featherlight high-performance binoculars. High-index BAK-4 prisms and fully multi-coated optics for high-fidelity images. Soft leatherette covering. Tripod adaptable.

8x42	6.5° field	**$189**
7x50	6.0° field	**$199**
10x50	WA 5.3° field	**$199**

MegaView™ 80mm Binoculars



Premium giant binoculars with high-power optics and cross-reinforced aluminum body and sliding tripod mounting post for optimum balance. Fully multi-coated 80mm lenses with BAK-4 prisms. Long eye relief.

15x80	3.5° field	**$429**
20x80 WA	3.5° field	**$439**
30x80 WA	2.3° field	**$449**

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BY MARTIN RATCLIFFE AND ALISTER LING

AUGUST 03

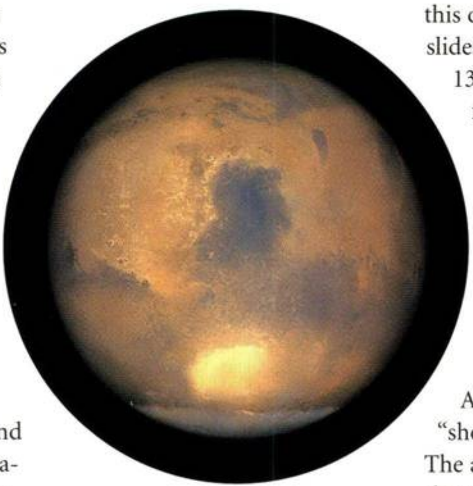
After months of building excitement, it's finally here — the best appearance of the Red Planet any of us ever will see.

Mars lights up the night

Has all the hoopla surrounding Mars been overkill? Not really. After all, the Red Planet comes closer to Earth in August than at any time in the past 50,000 years. This gives observers their best chance ever to see features on the only planet that shows true surface detail.

Take advantage of every opportunity to gaze at Mars through your telescope this month. And if you have the chance, use bigger and better scopes. Contact your local astronomy club or planetarium to learn about public observing events in the area. Don't worry if the sky appears hazy. The same weather conditions that trap haze and humidity usually mean a stable air mass with little or no turbulence. So sultry summer evenings often provide great "seeing" — and some of the best views possible. The view should improve even further by late evening, once Mars has climbed higher in the sky.

In case of bad seeing or a global dust storm on Mars, be prepared to point your telescope elsewhere. Focus on the Moon to watch sunlight and shadows march across crater floors. The terminator — the line that divides light from dark — marks the region where the fastest action takes place. Look for starlike points just on the dark side, where the first (or last) rays of sunlight catch high mountain peaks or elevated crater rims.



MARS APPEARS BETTER in August than at any time in recorded history. To get a better view, you'd have to be on a spacecraft like Mars Global Surveyor, which took this image. NASA/JPL/MSSS

Did you know that the Moon orbits Earth once every 27.3 days, but takes 29.5 days on average to go from one full phase to the next? Mars, now moving fairly slowly relative to the background stars, serves as a convenient reference to see this difference. As the Moon slides north of Mars on August 13, it appears one day past full phase. Next month, the Moon will be a day short of full as it glides past the Red Planet. And by December, it will appear half-lit next to Mars.

Anyone who has gone camping in mid-August has seen lots of "shooting stars" and satellites. The annual Perseid meteor shower hits its peak this year on the night of August 12/13. Although glare from the Full Moon will drown out fainter meteors, it's still a great time to sit around a campfire with family or friends and look up at the sky. You can even "listen" to meteors. Tune to the frequency of a strong FM radio station from a city at least a couple hundred miles away. Meteors arise when dust particles from old comets burn up high in the atmosphere, and their ionized trails reflect radio waves. Most of the time you will hear faint static, but every few minutes a burst of the radio station's signal will come through, some brief while others may last 30 seconds.

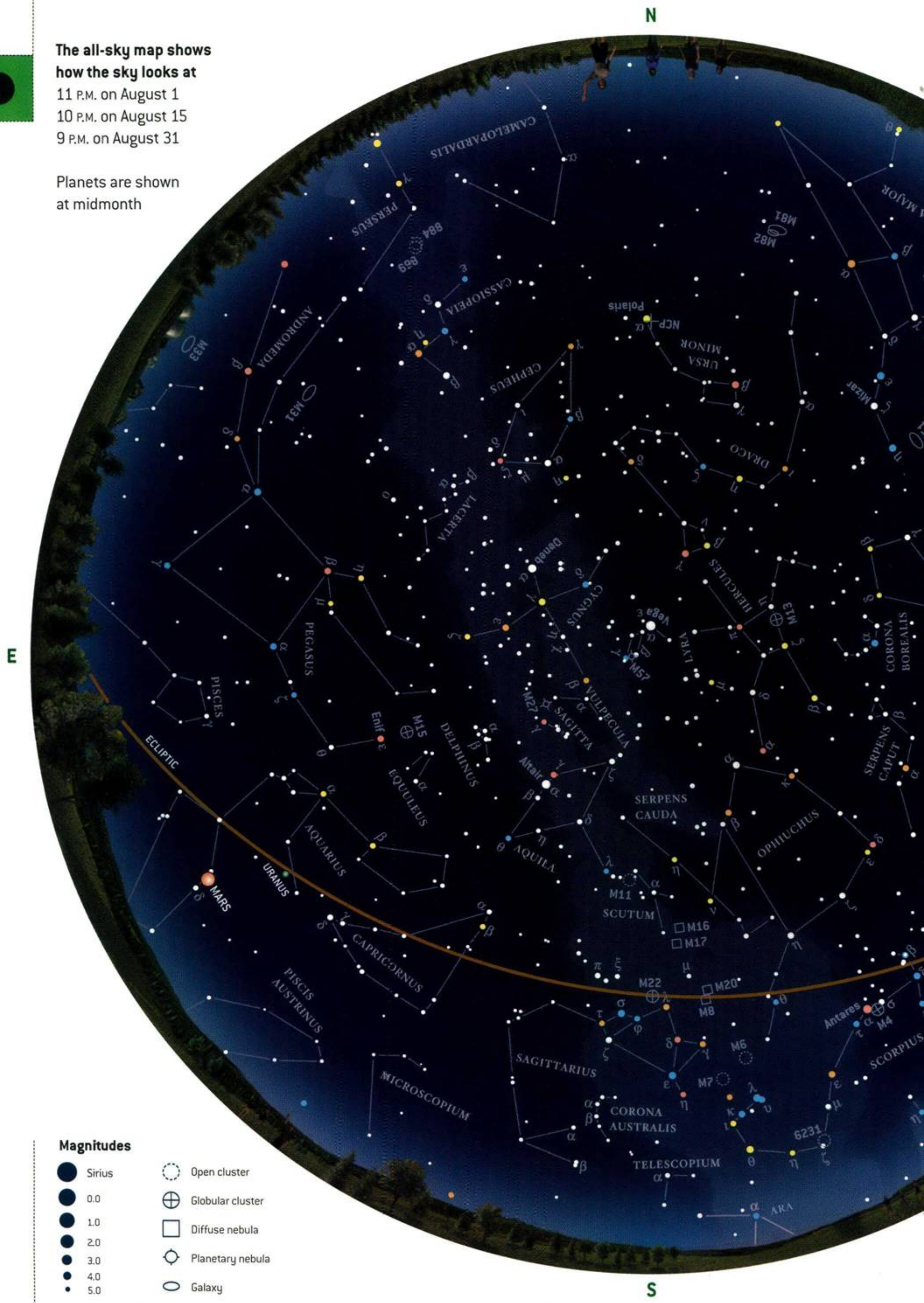
The easiest satellite to follow across the sky is the International Space Station. The brightest ones, however, are Iridium satellites, which predictably flare in brightness as the Sun glints off their solar panels. You can find local predictions for viewing all these satellites and more at www.heavens-above.com.

One of the favorite events for many amateur astronomers is a summer star party. Just about every state or province has one, usually on a weekend around a New Moon. Under dark skies, observers gather to view just about everything, from Mars to Pluto and asteroids to quasars. Friendly folk often give visitors a tour of the sky's splendors. Chances are one of the big scopes will be pointed at the Veil Nebula, an exquisite supernova remnant. See "Coming events" on page 110 for a list of star parties, or check Astronomy.com for one near you.

While you're in a dark field around midnight, look for your shadow cast by Mars. At the end of August, the Red Planet blazes away at magnitude –2.9. Slowly move from side to side, using peripheral vision to see if you can detect the motion on the ground.

The all-sky map shows how the sky looks at
11 P.M. on August 1
10 P.M. on August 15
9 P.M. on August 31

Planets are shown at midmonth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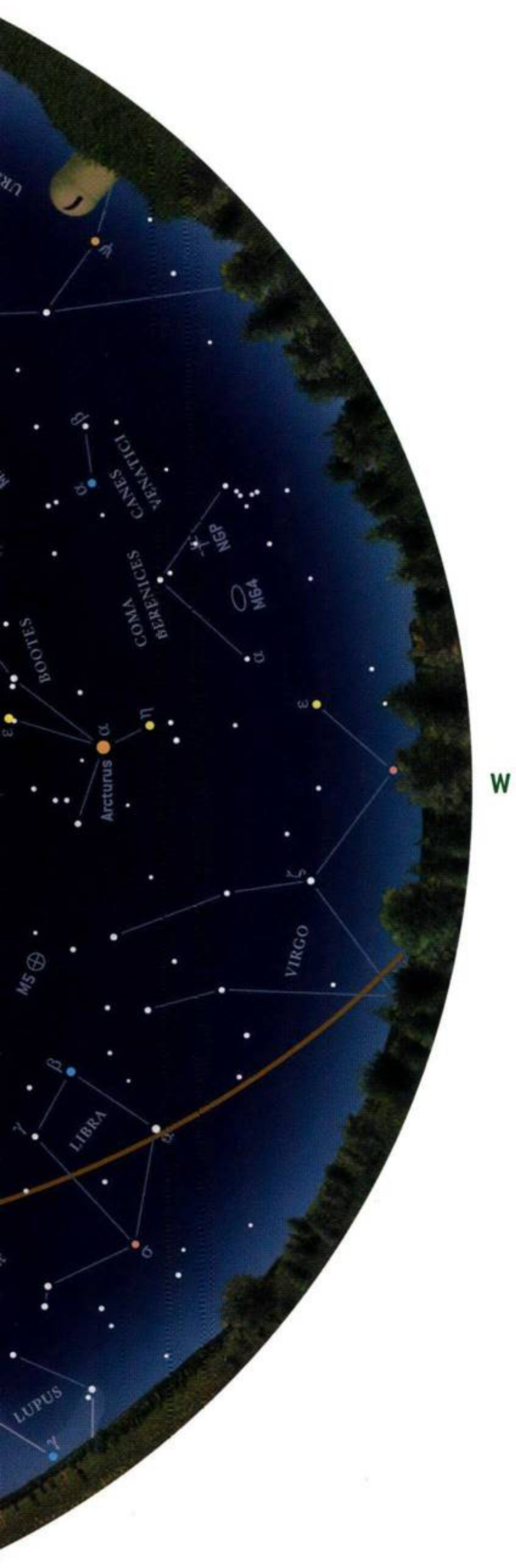
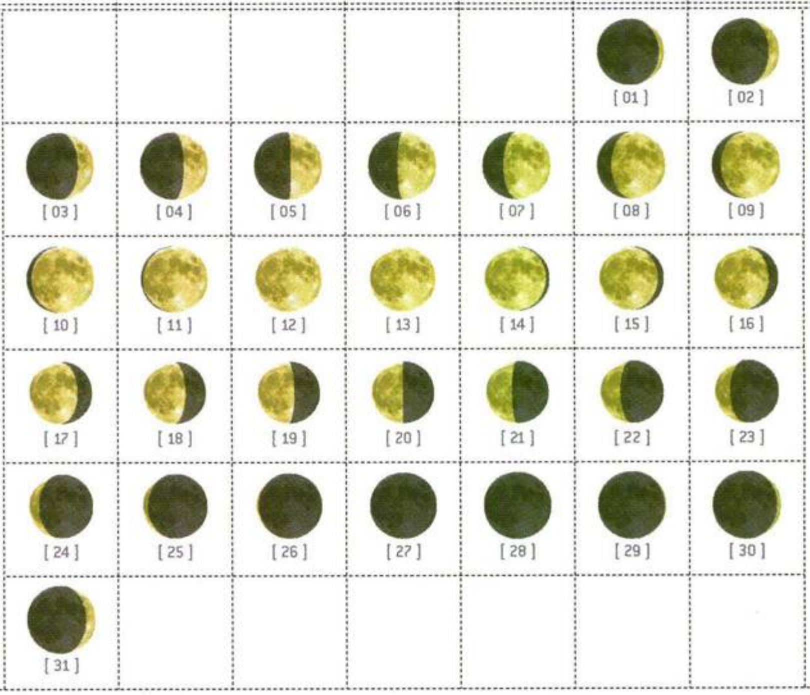
M31
CEPHEUS
Mizar
DRACO
LACERTA
Deneb
CYGNUS
HERCULES
M13
Vega
LYRA
M57
CORONA BOREALIS
PEGASUS
PISCES
ECLIPTIC
Enif
M15
DELPHINUS
M27
SAGITTA
VULPECULA
Altair
EQUULEUS
SERPENS CAUDA
SERPENS CAPUT
OPHIUCHUS
AQUARIUS
AQUILA
URANUS
MARS
M11
SCUTUM
M16
M17
CAPRICORNUS
M22
M20
M8
Antares
M4
SCORPIUS
PISCIS AUSTRINUS
M6
SAGITTARIUS
M7
MICROSCOPIUM
CORONA AUSTRALIS
6231
TELESCOPIUM
ARA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions:
horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sk



north, south, east, and west. To find stars above your
.

august 03



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[24]	[25]	[26]	[27]	[28]	[29]	[30]
[31]						

04 Neptune is at opposition, 10 A.M. EDT

05 First Quarter Moon is at 3:28 A.M. EDT

06 The Moon is at perigee (229,555 miles from Earth), 10:03 A.M. EDT

12 Full Moon is at 12:48 A.M. EDT

The Moon passes 5° south of Uranus, 8 P.M. EDT

13 Perseid meteor shower peaks

The Moon passes 1.9° north of Mars, 1 P.M. EDT

14 Mercury is at greatest eastern elongation (27°), 5 P.M. EDT

18 Venus is in superior conjunction, 2 P.M. EDT

19 The Moon is at apogee (251,097 miles from Earth), 10:22 A.M. EDT

19 Last Quarter Moon is at 8:48 P.M. EDT

22 Jupiter is in conjunction with the Sun, 6 A.M. EDT

23 The Moon passes 4° north of Saturn, 10 A.M. EDT

24 Uranus is at opposition, 6 A.M. EDT

27 Mars is closest to Earth (34.6 million miles away), 6 A.M. EDT

New Moon is at 1:26 P.M. EDT

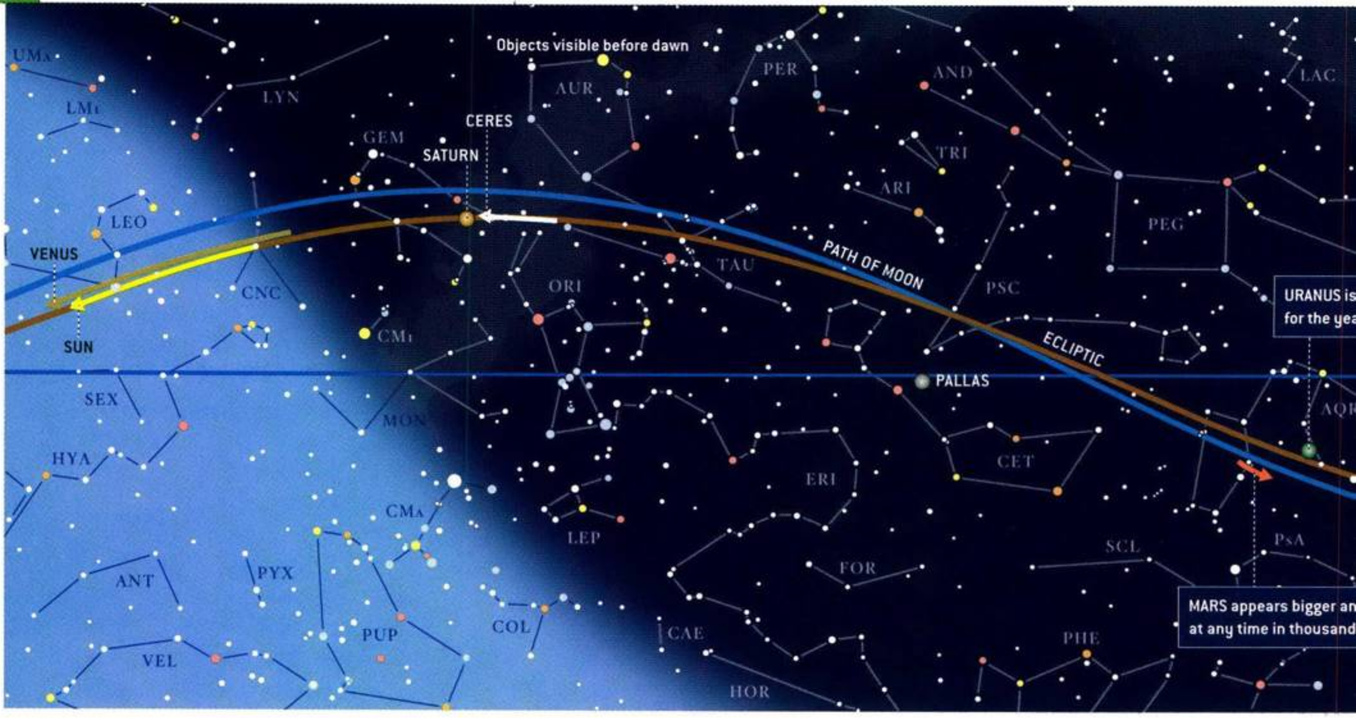
28 Mars is at opposition, 2 P.M. EDT

30 Mars is at perihelion (128.4 million miles from the Sun), 7 A.M. EDT

31 The Moon is at perigee (228,618 miles from Earth), 2:48 P.M. EDT

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and s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LMi
LYN
LEO
VENUS
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Objects visible before dawn
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FOR
PATH OF MOON
ECLIPTIC
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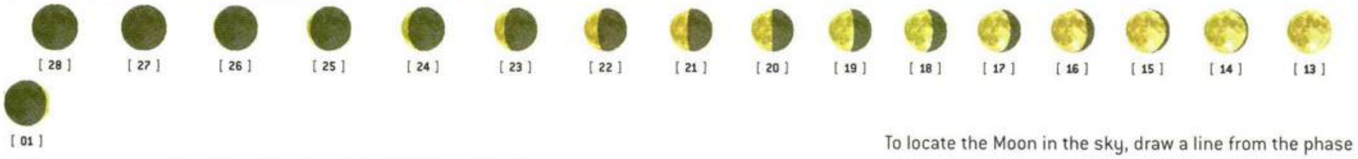
URANUS is
for the yea

MARS appears bigger an
at any time in thousand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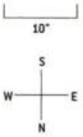
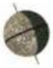
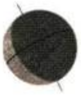
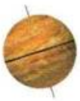
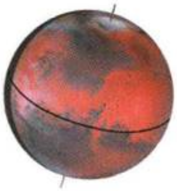
To locate the Moon in the sky, draw a line from the phase

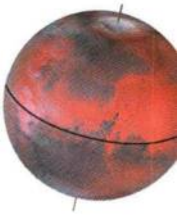








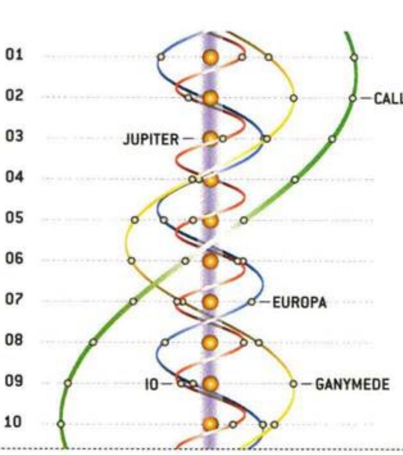


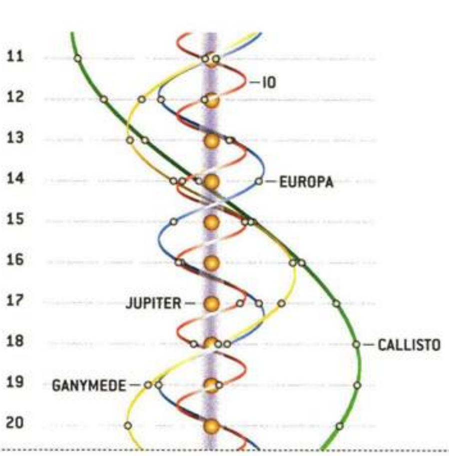


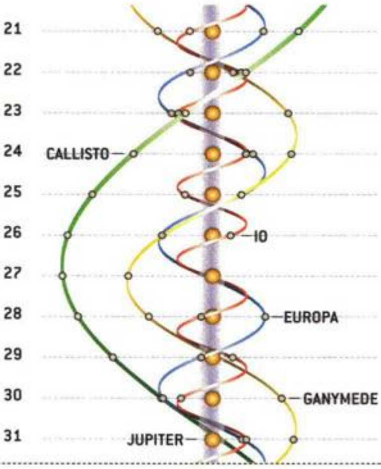
PLANETS	MERCURY	MERCURY	VENUS	MARS
Date	August 1	August 31	August 15	August 1
Magnitude	–0.1	1.6	–3.9	–2.3
Angular Size	6.1"	9.8"	9.6"	22.4"
Illumination	69%	19%	100%	96%
Distance (AU) from Earth	1.099	0.683	1.730	0.419
Distance (AU) from Sun	0.442	0.429	0.719	1.387
Right Ascension (2000.0)	10h16.8m	11h38.5m	9h34.0m	22h55.8m
Declination (2000.0)	11°09'	–2°21'	15°47'	–13°29'

Jupiter's moons

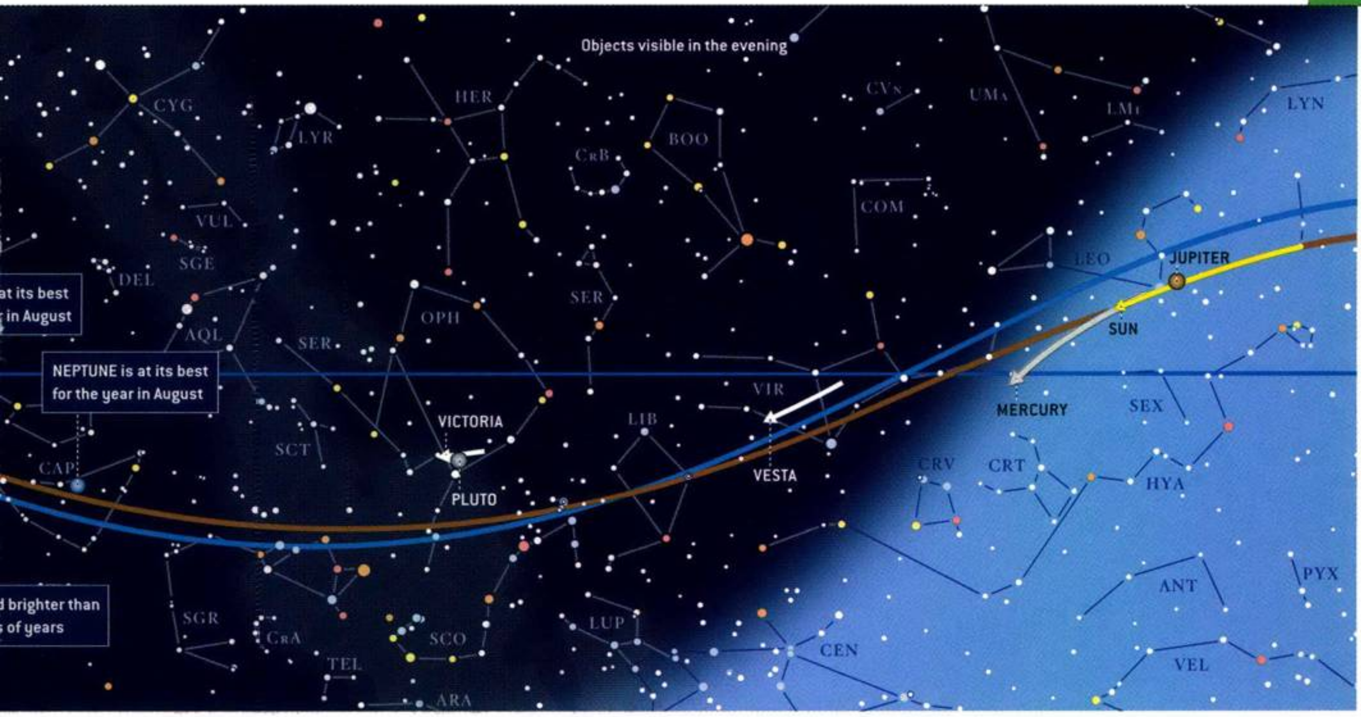
Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view in a telescope.







uares show motions and locations of solar system objects during the month.


Objects visible in the evening
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LYR
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at its best
in August

NEPTUNE is at its best for the year in August

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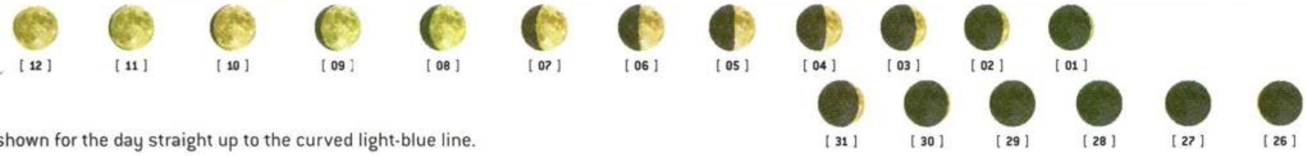
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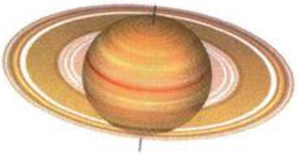
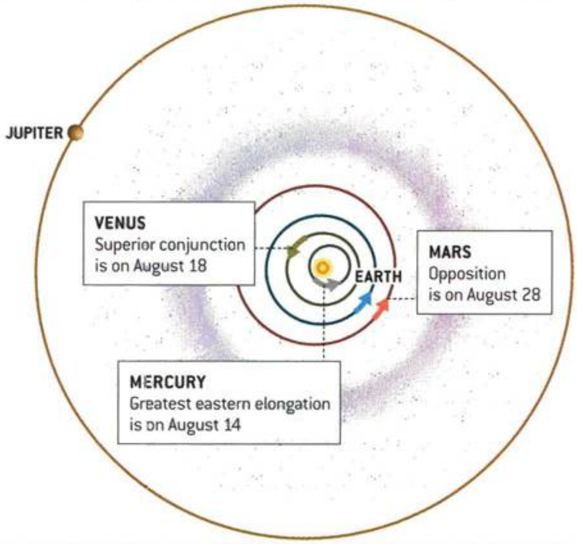
shown for the day straight up to the curved light-blue line.



MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
August 31	August 1	August 15	August 15	August 15	August 15
−2.9	−1.7	0.1	5.7	7.8	13.8
25.1"	31.1"	17.1"	3.7"	2.3"	0.1"
100%	100%	100%	100%	100%	100%
0.374	6.335	9.747	19.030	29.081	30.239
1.381	5.367	9.031	20.030	30.079	30.683
22h34.9m	9h47.3m	6h38.5m	22h13.9m	20h55.6m	17h08.1m
−16°00'	14°12'	22°23'	−11°48'	−17°21'	−13°37'

The planets in their orbits

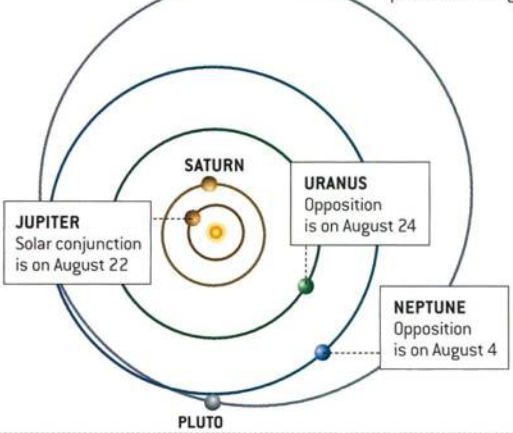
Arrows and dots show planets' positions during the month.


JUPITER
EARTH

VENUS
Superior conjunction is on August 18

MARS
Opposition is on August 28

MERCURY
Greatest eastern elongation is on August 14


SATURN
PLUTO

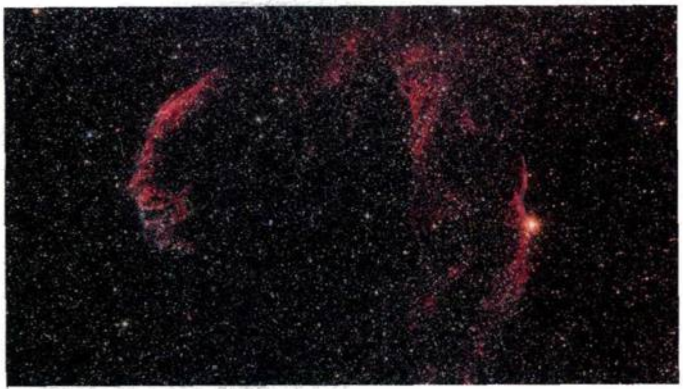
JUPITER
Solar conjunction is on August 22

URANUS
Opposition is on August 24

NEPTUNE
Opposition is on August 4

THE DEEP SKY

Several glittering jewels dot the expansive Milky Way in Cygnus the Swan, but the most intriguing spectacle may be the tattered remnant of a star that blew itself apart.



THE VEIL NEBULA consists of gas enriched with heavy elements rushing from the site of a star that exploded 30,000 years ago. BILL AND SALLY FLETCHER

Subtle but splendid

Whether you observe alone from a city backyard or with hundreds of others at a star party, Cygnus holds treasures galore. Summer's magnificent celestial swan appears best as it soars overhead on August evenings. Cygnus has a host of colorful double stars, none more famous than Albireo. Also known as Beta (β) Cygni, and labeled as such on the circular star map on the facing page, it marks the head of the swan. Without doubt, Albireo is the most lovely colored pair in the northern sky: a blue sapphire offsetting a brighter yellow topaz.

Keep these colors in mind and sweep your scope northeast past 2nd-magnitude Epsilon (ε) Cygni to 61 Cygni. Staring back at you in a low-power eyepiece will be a pair of yellow-orange stars, not quite equal in brightness. Bump up the power a bit and take them slightly out of focus to show off their true colors. Most people judge their hue to be deeper than Albireo's topaz.

This star system holds a special place in the history of science because it was the first to have its distance measured, expanding our notions of just how big the universe might be. In 1838, German astronomer Friedrich Bessel measured subtle changes in its position over the course of a year, reflecting our changing perspective as Earth revolves around the Sun. Using simple geometry, Bessel concluded that 61 Cygni lies some 10.3 light-years away. The modern value stands at 11.4 light-years, making it the fourth-closest naked-eye star system after Alpha Centauri, Sirius, and Epsilon Eridani.

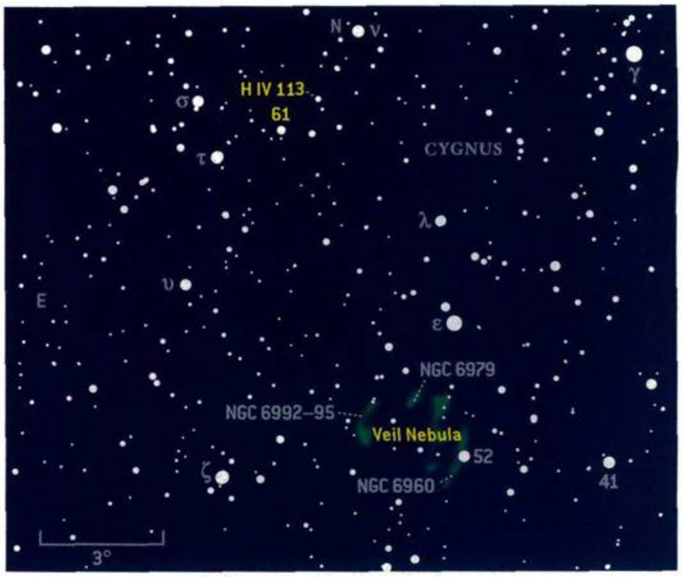
Just 1° northwest of 61 Cygni lies another interesting pair. Sir William Herschel, the father of deep-sky observing, discovered this duo and cataloged it as H IV 113. Although not as glorious as Albireo, the brighter component appears a striking blue in contrast to the subtle yellow of the secondary.

The mesmerizing Veil

If you head to a star party this summer, ask the owner of a large telescope to show you the Veil Nebula in an OIII filter (pronounced oh-three). Considered a challenging object for 6- and 8-inch scopes back in the 1950s and '60s, the Veil shows impressive structure in a 12-inch or bigger scope armed with a modern nebula filter.

The beauty of the apparently intertwining filaments as they spill out of the field of view defies description. Although you will never spot the fine-scale detail visible in photographs, there's something truly special about seeing the nebula with your own eyes. To get the most out of the view, be aware that OIII filters have a reflective coating that scatters light unless you've got it well shrouded. If you are holding the filter (as many observers do), cup your hands or use a dark hood to eliminate any interfering light.

The Veil Nebula represents the expanding remnant of a supernova that exploded some 30,000 years ago. This tenuous cloud has now broken into three primary sections that are quite a distance apart. The two outside arcs — NGC 6960 on the west and NGC 6992–95 on the east — appear brighter and contain the more impressive structures. Yet the middle part, known as Pickering's Triangle (NGC 6979), is quietly magnificent, thanks to its tangle of strands that taper into a long, graceful, S-shaped thread.



Martin Ratcliffe *is former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist with Environment Canada.*

THE PLANETS

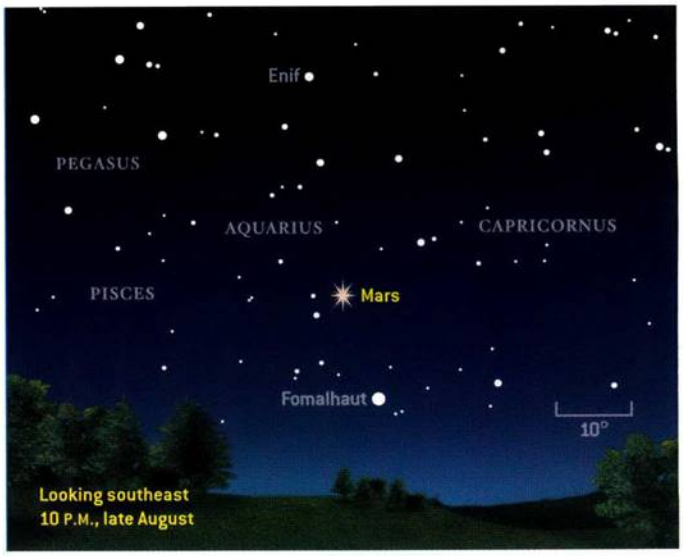
While Mars garners most of the headlines as it reaches the peak of its glorious apparition, two distant gas giants also put on their best displays of the year.

Late August finds Mars closer to Earth than at any time in many millennia. Around the 28th — the date it lies opposite the Sun in our sky — Mars appears bigger and brighter than any of us ever have seen. Although it remains *the* story this month, Mars isn't the only story. Uranus and Neptune also come to opposition, so they also appear at their best.

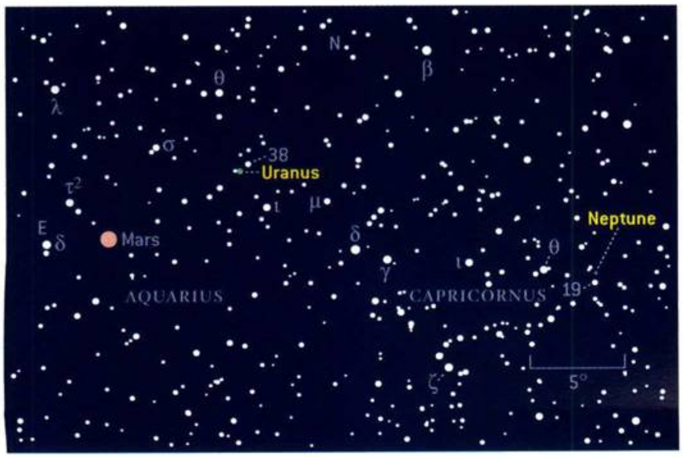
Before Mars rises to a decent altitude in late evening, you can prepare for the night's observing by hunting down Mercury and Pluto. The nearest and farthest planets from the Sun often prove to be the two most challenging to see. **Mercury** always stays close to the Sun in our sky, and this month it appears only briefly after sunset. It reaches greatest eastern elongation on August 14, when it shines at magnitude 0.4. Although Mercury appears slightly brighter in early August, it's still difficult to see because it sets just one hour after the Sun.

Pluto will soon join Mercury in the Sun's glare. Yet in early August, at least, it stays high enough in the evening sky to warrant a look. Glowing faintly at magnitude 13.8, it's a challenge for an 8-inch scope and nearly impossible in anything smaller. Pluto lies in Ophiuchus, about 2° north of 2nd-magnitude Eta (η) Ophiuchi. To find it, use the detailed map on page 77 of the June 2003 *Astronomy*, also available at Astronomy.com.

By late evening, **Mars** dominates the sky. It begins the month less than 3° north of 3rd-magnitude Delta (δ) Aquarii. Slowly at first, Mars moves westward against the background stars of Aquarius. Its normal easterly motion gets reversed near opposition as the faster-moving Earth overtakes it. Mars also brightens rapidly during August, climbing from magnitude –2.3 on the 1st to magnitude –2.9 at month's end. This 75 percent increase makes it noticeably brighter than Jupiter was at its best early this year.



Looking southeast
10 P.M., late August



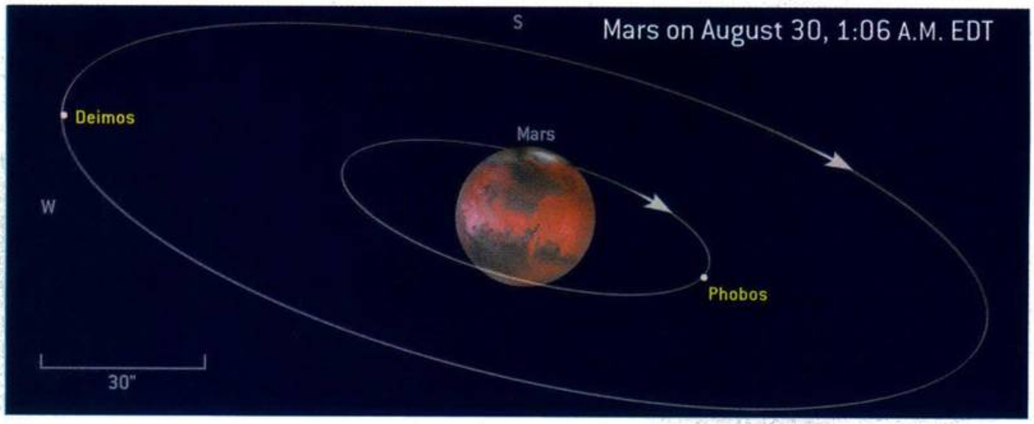
The Red Planet shines so brilliantly because opposition occurs just two days before its August 30 perihelion — its closest approach to the Sun. The interplay between Mars's noticeably elliptical orbit and Earth's more circular one brings Mars closest to Earth on the 27th, when the planet lies 34,646,000 miles (55,758,000 kilometers) away.

Throughout August and September, Mars spans more than 20". It starts August with an apparent diameter of 22.4" and grows to 25.1" by the 27th. Telescopic views render Mars nearly the same apparent size as the prominent lunar crater Eratosthenes. So if your scope shows detail inside this crater, it should do well with Mars.

Your reaction to Mars's telescopic appearance will depend on your expectations. If this is your first look at Mars at a close approach, don't be surprised by how small it appears. The dramatic pictures and wonderful words used to describe this apparition come in the context of more distant ones. Mars really does appear much bigger than normal — but it remains tiny in most backyard scopes.

Opposition also offers a rare opportunity to glimpse the two small moons of Mars: Phobos and Deimos. Many observers consider these objects beyond the range of backyard telescopes, but they have been seen in telescopes as small as 8 inches. Like Mars, the moons peak in brightness at opposition, so late August is the time to give them a shot.

Although Phobos and Deimos are faint — at opposition they glow at magnitudes 10.4 and 11.5, respectively — the biggest obstacle to spotting them comes from their proximity to the planet's brilliant disk. At best, Phobos lies 22" and Deimos 74" from the limb of Mars. The best time to search for the moons is when they lie farthest from the planet. The table at right gives times when they are at their maximum distance east of Mars; they appear farthest west halfway between these times. To spy the moons, place Mars just outside the field or use an occulting bar to block Mars's disk. To learn more about observing Mars during this historic apparition, see "Get ready for Mars" on page 80.



Mars on August 30, 1:06 A.M. EDT

/// EASTERN DAYLIGHT TIMES OF GREATEST EASTERN ELONGATIONS

	Deimos	Phobos			
22	—	1:50 A.M.	9:30 A.M.	5:08 P.M.	
23	2:48 A.M.	12:46 A.M.	8:24 A.M.	4:04 P.M.	11:44 P.M.
24	9:06 A.M.	7:24 A.M.	3:04 P.M.	10:44 P.M.	
25	3:24 P.M.	6:24 A.M.	2:02 P.M.	9:40 P.M.	
26	9:36 P.M.	5:18 A.M.	12:58 P.M.	8:38 P.M.	
27	—	4:18 A.M.	11:56 A.M.	7:34 P.M.	
28	3:54 A.M.	3:12 A.M.	10:52 A.M.	6:32 P.M.	
29	10:12 A.M.	2:12 A.M.	9:50 A.M.	5:28 P.M.	
30	4:30 P.M.	1:06 A.M.	8:46 A.M.	4:26 P.M.	
31	10:42 P.M.	12:06 A.M.	7:44 A.M.	3:22 P.M.	11:00 P.M.

Sweep less than 10° west of Mars to find the giant planet **Uranus**. Despite their proximity in the sky, the two planets are nowhere near each other in space. Mars lies a mere one-third the average Sun-Earth distance (a distance called the astronomical unit) from us, while Uranus stands 19 astronomical units away, or 1.77 billion miles. So even though Uranus is more than seven times the diameter of Mars, it appears smaller because it lies more than 50 times farther away. Seen through a telescope, Uranus measures about one-seventh the size of Mars — only 3.7" across.

Because Uranus lies a few degrees west of Mars in our sky, it reaches opposition just a few days earlier, on August 24. Glowing at magnitude 5.7, it's an easy target in binoculars. You can even glimpse it without optical aid under a clear, dark sky. It appears to form a wide double with the 5th-magnitude star 38 Aquarii, which itself lies due south of Alpha (α) Aquarii. To avoid confusion with 38 Aquarii, remember that Uranus lies east of the star in early August, but by the end of the month it has moved to a position almost due south of the star.

In a telescope, Uranus displays a tiny disk that appears distinctly different from a pointlike stellar image. You might also notice its subtle blue-green hue. On a night of steady seeing, try higher powers to bring the disk more clearly into view.

Neptune lies even farther west than Uranus, in Capricornus, where it reaches opposition on August 4. This distant gas giant lies 10 astronomical units beyond Uranus, at a staggering distance of 2.7 billion miles. At this range, Neptune subtends just 2.3". You'll need a pair of large binoculars, say 20x80, or a telescope to pick out Neptune with any ease. It glows at magnitude 7.8 throughout August, just 15 percent as bright as Uranus. Simply finding it can prove a challenge.

The 4th-magnitude star Theta (θ) Capricorni serves as an easy guide to the eighth planet. Neptune begins August lying just 2.0° west of the star, which lies in the north-central part of the constellation. The planet drifts westward this month, passing 0.5° north of 19 Capricorni on the 25th. This 6th-magnitude star is easy to spot in binoculars.

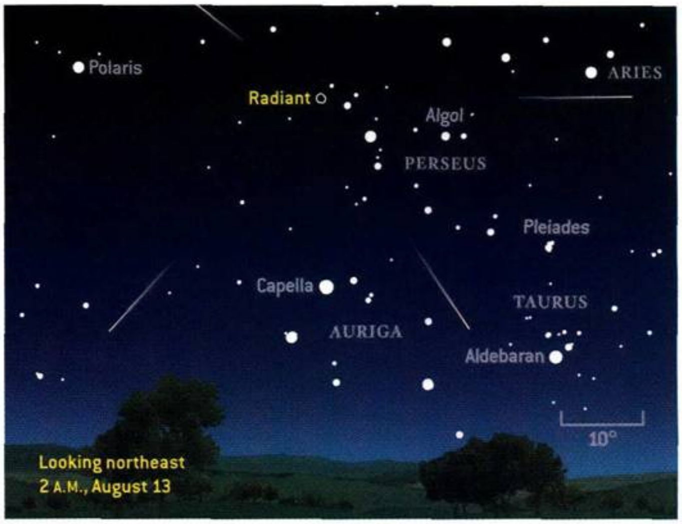
Jupiter reaches solar conjunction, a position directly behind the Sun from our point of view, on August 22. It disappears from view during the first week of the month. **Venus** precedes Jupiter into the solar glare, passing behind the Sun on August 18, and can't be seen at all.

Fortunately, **Saturn** returns to view in the early morning hours. The ringed planet rises around 3 A.M. in mid-August among the stars of Gemini. Shining at magnitude 0.1, it matches the brightness of Capella. Mark the morning of August 23 on your calendar — that's when a glorious crescent Moon hangs 4° north of Saturn as twilight begins. At the same time, the brilliant stars in Orion, Gemini, Canis Major, and Canis Minor join Saturn. The stunning collection offers a grand vista as twilight starts to paint the sky.

METEORS AND MOONS

The year's most eagerly anticipated meteor shower peaks at the time of Full Moon. If the Moon hinders meteor viewing too much, take the opportunity to view an obscure limb feature tipped in our direction.

A PERSEID METEOR shoots across the sky just south of Andromeda during the 1997 shower. JUDY HECKENBACH

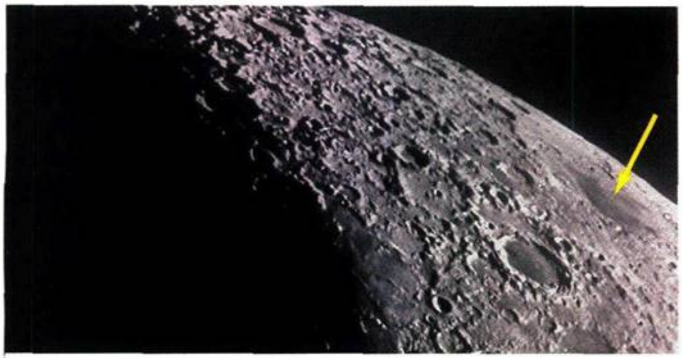


Looking northeast
2 A.M., August 13

Perseids vs. the Moon

The peak of the annual Perseid meteor shower arrives on the morning of August 13 — just one day after Full Moon. That means bright moonlight will interfere significantly, wiping out fainter meteors. But don't give up. The Perseids tend to be bright and often leave persistent trains, so some good activity should shine through the unwanted light. If the thought of viewing the shower in competition with the Moon bothers you, watch as activity rises in early August instead.

Meteors always appear better in the early morning hours because that's when we are watching from the leading hemisphere of Earth. (It's the same reason a car driving through rain picks up more rain on the front windshield than the rear one.) The Perseids derive from Comet 109P/Swift-Tuttle. Each time this comet passes close to the Sun, it sheds dust particles, most no bigger than a grain of sand. When Earth runs into this stream of debris at 37 miles per second (59 km/sec), our atmosphere incinerates the particles, producing the streaks of light we call meteors.



MARE HUMBOLDTIANUM (arrow) is normally hidden from view, but observers can glimpse it when the Moon's northeastern limb tips in our direction. FROM THE *CONSOLIDATED LUNAR ATLAS* (LPL/UA)

Mare Humboldtianum

Any feature near the limb of the Moon changes significantly in appearance over the course of a lunar month (or lunation). Although the Moon rotates once on its axis in the time it takes to revolve once around Earth, the two rates are not precisely linked. Therefore, the Moon rocks gently back and forth from our perspective — a phenomenon called libration — and allows us to see features not normally visible. A favorable libration occurs when one lunar limb swings toward us more than usual. This happens to the Moon's northeastern limb from August 10 to 12.

One feature, Mare Humboldtianum, rarely appears without a favorable libration. Named after the German naturalist Alexander von Humboldt, it ranks among the smaller lunar "seas," spanning about 100 miles. Also look for the crater Belkovich, which lies on the northeastern flank of Mare Humboldtianum. Few people have ever seen these features. Search for them very close to the limb just before Full Moon. Further opportunities arise in coming months a few days earlier in each lunation. For example, by October, the libration becomes favorable for viewing Mare Humboldtianum around *the First Quarter* Moon on October 31.

COMETS AND ASTEROIDS

A faint periodic comet glides slowly through the Teapot of Sagittarius, and a 10th-magnitude asteroid pays a visit to the Box Nebula.

A star-party comet

We're going to be terribly spoiled in half a year: Two naked-eye comets should be arcing across the spring sky. Fresh comets, and especially the timing of their appearance, are mostly random events. To be sure, we know the orbits of many periodic comets and where they'll be. Like the planets, they each have their own clocks. But few of the known periodic comets put on great displays, with the occasional exception of Comet 1P/Halley. Sometimes fresh comets arrive spread apart the way Saturn, Jupiter, and Mars are this year, or they can clump together like the planets during last year's great conjunction. When they arrive in groups, it usually means that before and after there's a bit of a drought — and that's what we've got right now.

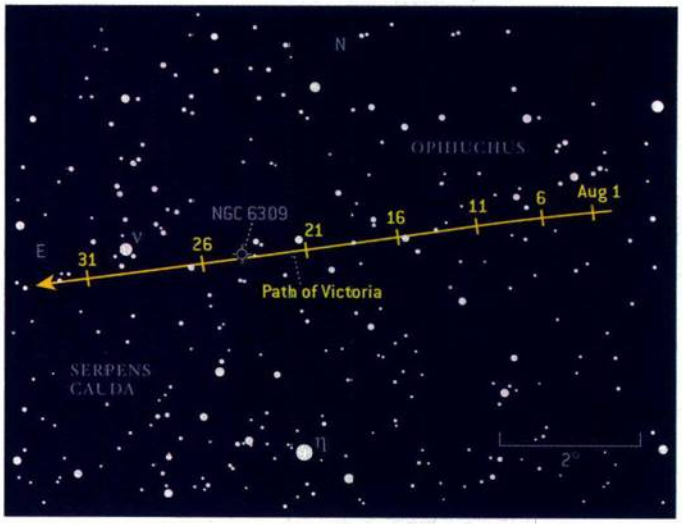
Barring the arrival of a surprise visitor, the brightest comet this summer will be 65P/Gunn, hovering at a modestly faint 12th magnitude. This makes it quite a bit fainter than any Messier object and will require a dark sky at New Moon if you want to see it.

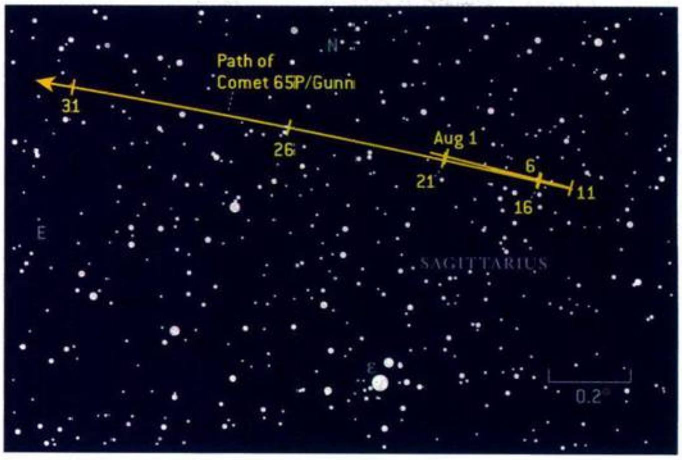
Set your sights on the 2nd-magnitude star Epsilon (ε) Sagittarii, at the lower right of the "Teapot" asterism now at its highest in the south during late evening. All month the faint fuzzball lies less than 1° north of this star. The comet moves slowly because Earth is overtaking it on the inside of the solar system racetrack, so it appears to come to a standstill and then retrace its steps. If you're a novice, the comet will be a challenge to see through an 8-inch scope. You'd be better off asking a big-scope owner if he or she can coax it out of the background.

/// ASTEROID POSITIONS

ASTEROID 12 VICTORIA

{Date}	{R.A.}	{Dec.}
August 1	16h53.6m	–12°18'
August 6	16h56.5m	–12°23'
August 11	17h00.3m	–12°30'
August 16	17h04.9m	–12°40'
August 21	17h10.3m	–12°51'
August 26	17h16.3m	–13°03'
August 31	17h23.1m	–13°16'





Vesta bows to a queen

Earth continues to pull ahead of the 300-mile-wide (500-km-wide) rock 4 Vesta. At its closest in March, this asteroid was an easy target in binoculars from any backyard. As we separate, Vesta continues to dim, dropping to 8th magnitude this month. With some care, you can still use binoculars to locate it about 8° north of the bright blue-white star Spica in Virgo, in the southwestern sky as darkness falls.

On September 13, 1850, British astronomer J. R. Hind discovered the twelfth asteroid located between the orbits of Mars and Jupiter. He named the asteroid 12 Victoria after the Roman goddess of victory — and in honor of the reigning monarch, Queen Victoria. Because it measures only 73 miles (117 km) across, Victoria doesn't often cross the 10th-magnitude threshold as it does this summer.

Use the map above to zoom in on Victoria's location, taking care to avoid the nights of bright moonlight from August 5 to 10. Because Victoria glows about as brightly as the fainter stars, you'll probably need to use the tried-and-true method of asteroid identification: Make a sketch of the field and then return a night or two later to see which "star" moved.

A nice bonus comes on the 24th, when Victoria skims just south of NGC 6309, an 11.5-magnitude planetary nebula nicknamed "The Box." Bump up the power to 150x or more to get a good view of it. Unlike the nebula, Victoria won't show the slightest hint of a disk or structure. ◼

EXPLORE

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JEFFREY S. KARGEL, U.S. Geological Survey, Flagstaff, AZ

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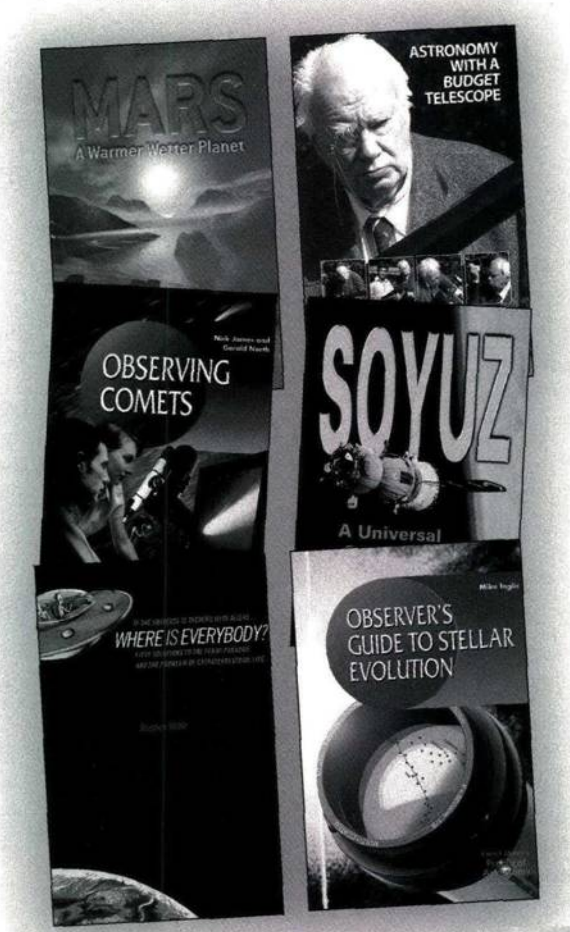
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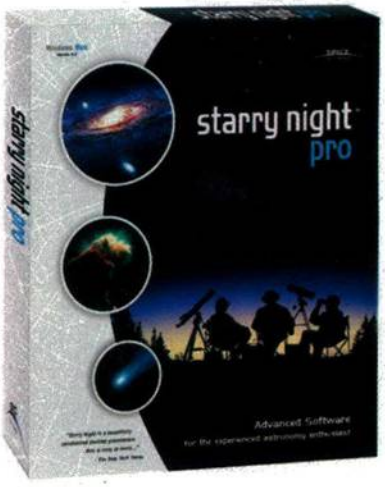

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Earth's magnetic field, planet speeds, black hole existence

EARTH'S MAGNETIC FIELD

I read recently that Earth's magnetic field is growing constantly weaker, and that within one or two thousand years it may disappear. What will be the consequences of this for life on Earth? Could this event be related to mass extinctions in the past? — **CARLOS PERLA-HERNÁNDEZ,** ZARAGOZA, SPAIN

BRIGHT, INTRICATE AURORAE should become more common at lower latitudes when Earth's magnetic field reverses, perhaps as soon as a thousand years from now. MARVIN NAUMAN

Earth's magnetic field is not vanishing in the sense that it is turning off. Instead, the strength of the dipole part of the global field — which gives Earth and many other planets north and south magnetic poles — is weakening at a rate of a few percent each century. But the total energy of the magnetic field, which is generated in Earth's interior, is not changing significantly.

It may be that Earth's field is currently in the process of slowly reversing direction so that the north magnetic pole and south magnetic pole flip-flop. Field reversals have occurred in the past; if the observed decay of Earth's dipole continues at the present rate, we would experience a field reversal in the next 1,000 to 2,000 years. (However, there is no particular reason to believe that this rate will continue.)

In any case, during a magnetic reversal, geophysicists expect the global field to become more complicated, with Earth's strong dipole being replaced by several weaker magnetic poles. This change could have a number of interesting consequences for humans. First, compasses would become far less useful navigational tools because Earth would contain a number of magnetic north poles rather than just one. Compass needles would point toward or away from their nearest magnetic pole.

Second, the reorganization of the field would decrease the altitude of Earth's protective barrier against the solar wind. This is currently located at roughly ten Earth-radii out, or 40,000 miles (64,000 kilometers). This decrease would directly expose many satellites in Earth orbit (such as communications and GPS satellites) to charged particles in the solar wind. Problems with electronics would be common, except for circuits specifically "hardened" against such radiation.

Third, aurorae would not be limited to the "northern lights" and "southern lights." Aurorae occur when energetic charged particles bombard the lower atmosphere near magnetic poles. Given many poles, aurorae would be seen in places they seldom are now.

Despite these effects, a field reversal would have minimal consequences for life on Earth. All life requires energy (from sunlight, volcanism, or another source), food (in the form of organic molecules), and liquid water to survive. Energy and food will be unaffected by a change in the magnetic field, and a magnetic field reversal happens too quickly (within a few thousand years) to expect a significant change in the overall amount of liquid water on Earth.

Animals and humans also require atmospheric oxygen, and land animals depend upon the high-altitude ozone layer for protection from solar ultraviolet radiation. Scientists believe that Earth's atmospheric oxygen and ozone layer exist thanks to the development of photosynthetic bacterial and plant life. In the absence of a global magnetic field, the solar wind would have direct access to Earth's atmosphere (as it does at both Venus and Mars) and the outermost portions of Earth's atmosphere could slowly be stripped away. This would include the removal of atmospheric oxygen vital for human and animal survival.

But don't worry — these solar wind processes would require tens of millions to billions of years to make significant changes to a planet's climate.

Would there be additional radiation at Earth's surface? No. Our planet's atmosphere is thick enough to stop most of the Sun's energetic particles.

Finally, field reversals occur every 500,000 years on average. Life on Earth started at least 3 billion years ago, and the great explosion of new forms of life in the Cambrian era occurred about 500 million years ago. So life has survived many reversals of Earth's magnetic field. There's no observed correlation between past magnetic field reversals and mass extinctions. — **DAVID BRAIN,** UNIVERSITY OF COLORADO

THE ACTIVE GALAXY M87 IN VIRGO harbors a supermassive black hole in its core, from which an energetic jet of high-speed particles emanates. NASA AND THE HUBBLE HERITAGE TEAM (STScI/AURA)

PLANET SPEEDS

Do all the planets travel around the Sun at the same speed?

— **MARK HOCKETT,** NEDERLAND, TEXAS

Not by a long shot. Even ancient astronomers realized that planets closer to the Sun moved faster than those farther away. (Of course, those astronomers didn't realize that the planets were actually orbiting the Sun.) Mercury races around the Sun at an average speed of 29.7 miles per second, while Earth moves briskly at 18.5 miles per second, and Pluto ambles along at 3.0 miles per second.

The great German astronomer Johannes Kepler first worked out the relationship between a planet's distance from the Sun and its period of revolution. He published this, his third law of planetary motion, in 1619 in *Harmony of the Worlds.* He showed that the square of the period of revolution (P^2) is proportional to the cube of its average distance (a^3). If the period is measured in years and the distance in astronomical units (the average distance between the Sun and Earth), the equation simplifies to $P^2 = a^3$. From the period and distance traveled, the planet's speed can be easily calculated.

To the accuracy of the measurements in Kepler's time, the equation worked exactly. Later in the 17th century, Sir Isaac Newton showed that the mass of a planet relative to the Sun also plays a role in the relationship between the planet's period and distance from the Sun. Because the Sun has so much more mass than any planet, however, this causes only a slight change to Kepler's law. — **RICHARD TALCOTT,** SENIOR EDITOR

BLACK HOLE EXISTENCE

Why is it so hard to prove that black holes exist if we can prove them in theory?

— **MATTHEW DWYER,** MT. JULIET, TENNESSEE

The key to the answer lies in the very word used to describe these objects: black. Black holes give off no light of their own, so the only way to prove they exist is through the effects they have on their environment.

Although a black hole radiates no light, theory suggests that its strong gravity would pull in material from its surroundings. That material would form a disk around the black hole, and friction would heat the matter to millions of degrees, causing it to glow brightly in x rays.

The first good evidence that black holes exist came in the 1970s from observations of the x-ray binary system known as Cygnus X-1, where a normal star revolves around an unseen companion. Calculations show the companion must weigh about eight times as much as the Sun. Any normal star that heavy would be obvious, yet nothing is visible. Still, astronomers could develop convoluted scenarios to explain Cygnus X-1 without resorting to a black hole, so the case wasn't settled.

The real proof came in the 1990s from observations with the Hubble Space Telescope. Hubble examined the core of the active galaxy M87 in Virgo. The telescope's superb resolution showed that gaseous material at M87's center whips around the core at more than a million miles per hour. To drive the gas to such a high speed requires a mass of two *billion* Suns — yet it had to be contained in a volume about the size of our solar system. Only a black hole could fit that bill, and supermassive black holes have since been confirmed in dozens of other galaxies. This finally proved the existence of black holes to all but the most die-hard skeptics. — **RICHARD TALCOTT,** SENIOR EDITOR

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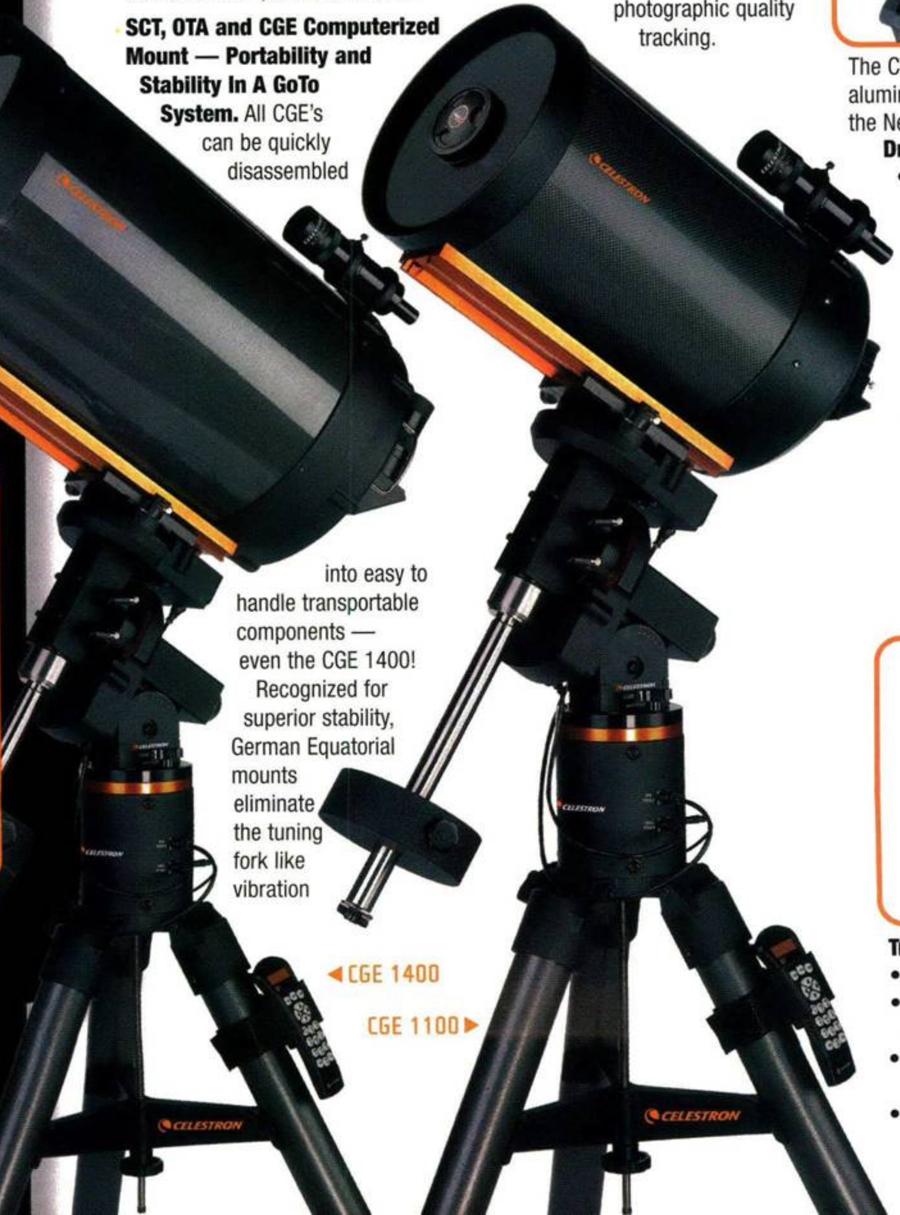

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Resolution (Rayleigh)	.68 arcseconds	.59 arcseconds	.50 arcseconds	.39 arcseconds
Coatings	StarBright®	StarBright®	StarBright®	StarBright®
Optical Tube	Carbon Fiber	Aluminum	Carbon Fiber	Aluminum
Fastar Compatible	Yes; f/1.95	No	Yes; f/2	Yes; f/2.1

STD. ACCESSORIES	CGE 800	CGE 925	CGE 1100	CGE 1400
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RA axis

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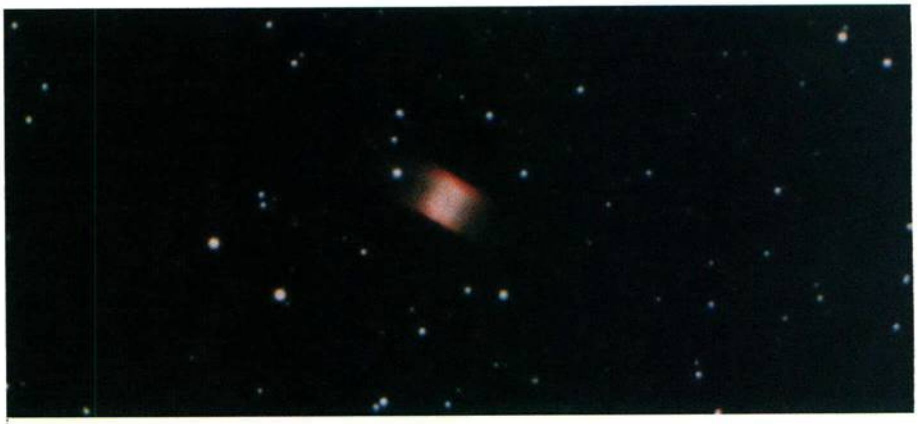
Lupus and Norma

On the fringes of the southern Milky Way, planetary nebulae, star clusters, and galaxies liven up the modest Wolf and Carpenter's Square. /// BY TOM POLAKIS

The skies become more and more starry in the hours preceding the celestial arrival of the Milky Way's center. In this region, the narrow stream of the Milky Way pools into a wide lake whose edges extend some 20° away from the plane of the galaxy's disk. The stellar activity picks up in the constellation Lupus the Wolf. A modest-sized constellation spanning 334 square degrees, it contains 10 stars brighter than 4th magnitude among a preponderance of fainter naked-eye stars. Many of them share the same distance: Six of the seven brightest members of Lupus are about 500 light-years away. However, it's difficult to form a wolf or any other pattern out of this jumble of bright stars.

Following Lupus to the meridian is Norma the Carpenter's Square. With all its stars dimmer than 4th magnitude, the diminutive constellation is noteworthy for the Norma star cloud. Similar in brightness to its northern counterpart, the Scutum star cloud, it's an oval enhancement 4° long and 2° wide in the Milky Way's band. The star cloud is several thousand light-years away and resolves into countless suns with the slightest optical aid. From the Southern Hemisphere, the Norma and Scutum star clouds are placed symmetrically around the galactic center.



IC 4406 looks like a long, rounded rectangle from our point of view, but if we were to see it at a different angle, we'd appreciate its true shape — a ring. We simply observe this celestial donut from the side. Distance estimates place the planetary nebula 5,000 light-years away. JACK MARLING

Begin on the western edge of Lupus near the Centaurus border to find the planetary nebula **IC 4406**. Small telescopes show a bright disk about 30" across that's uniform except for a bright rim. In medium apertures, its true character begins to emerge as flat extensions stretching east and west bring the length to 90". The central region has slight indentations resembling a dumbbell nebula, while the extensions appear remarkably straight with parallel walls. IC 4406 belongs to the class of bipolar nebulae characterized by a thin waist and two lobes. The central star remains visually out of reach, but its expelled outer layers form the vivid lobes by taking the path of least resistance through the star's polar regions. The waist is an equatorial torus of dense material.

Less than 2° east sits the bright type 2 Seyfert spiral galaxy **NGC 5643**. A 12-inch scope shows a faint haze surrounding a bar oriented roughly north-south. Averted vision brings out the western spiral arm, which curves very tightly around the core. The symmetrical eastern arm is more difficult to see. Detail in the galaxy is compromised by the presence of many overlain field stars. Look for one of them superposed on the southern end of the bar.

A detour into the thinner northern reaches of Lupus is rewarded by the sight of this month's first globular cluster. **NGC 5986** begins to reveal its brightest 13th-magnitude stars at high magnification in a 6-inch telescope. In a 12-inch, it becomes a fully resolved globe nearly 10' across and

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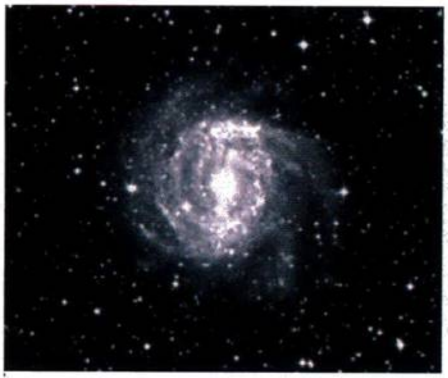
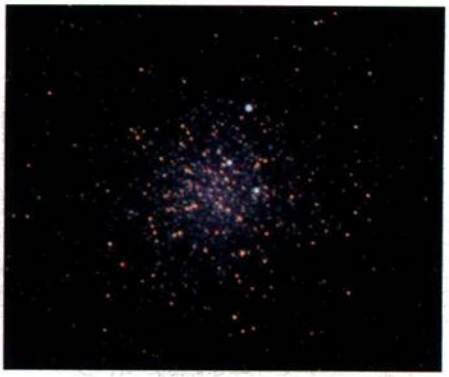
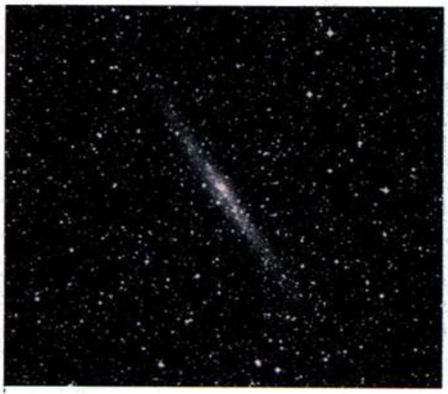
Tom Polakis *is an aerospace engineer who enjoys astrophotography and deep-sky observing.*



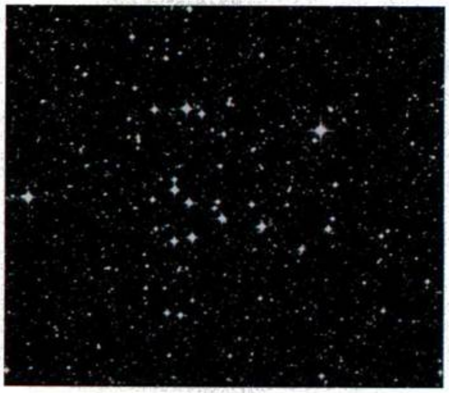
NGC 5643 is a face-on, barred spiral galaxy with faint, tightly wrapped arms. The type 2 Seyfert galaxy appears in Lupus. DIGITIZED SKY SURVEY



NGC 5986 is closer to the galaxy's center than it is to Earth. The globular cluster was discovered by James Dunlop in May 1826. H. E. BOND/CTIO



ESO 274-1 is a thin spiral galaxy viewed nearly edge-on. It lies about 12 million light-years away. DIGITIZED SKY SURVEY



NGC 5749 is an open cluster that lies roughly 4,000 light-years away near the southern edge of Lupus. DIGITIZED SKY SURVEY

exhibits a bright center. A quarter degree east in the same low-power field are two stars of magnitudes 6 and 7. NGC 5986 lies 35,000 light-years from Earth and 15,000 light-years from the Milky Way's center. The globular's inferred orbit periodically carries it to within 6,000 light-years of the galaxy's center.

Pan 1.5° southwest of Epsilon (ε) Lupi to find a planetary nebula that is bright enough to exhibit impressive color. **NGC 5882** is an example of a planetary with disk, shell, and halo structure. The smallest inner structure is an ellipsoid viewed from its side. Surrounding this is a fainter, circular shell 15" across inside a faint halo 5' in diameter. In backyard scopes, only the circular shell is apparent. Use direct vision to see its beautiful blue-green hue.

An entirely different object sits just 1° to the south-southwest. **ESO 274–1** is a "flat" spiral galaxy viewed almost perfectly along its edge. It is obviously nearby, as its measured velocity puts it at a distance of 12 million light-years. Not so obvious is its possible association with the Centaurus Galaxy Group, which contains the stunning galaxy NGC 5128 (Centaurus A). ESO 274–1 has very low surface brightness but can be traced to over 10' in length in a 16-inch telescope. Even near the core, the width of the spindle is no greater than 1.5'.

The southern edge of Lupus holds the open cluster **NGC 5749**. Of its 30 stars, a dozen or so are visible in large binoculars. An 8-inch telescope shows a sprinkling of stars 7' across that is well distinguished from the surrounding star fields. It lies at a distance of about 4,000 light-years.

Before moving on to richer fields in Norma, we make a stop at the bright globular cluster **NGC 5927**. "Bright" doesn't refer to individual stars in this case, as the most luminous members of the cluster glow dimly at magnitude 14.6. A 13-inch telescope just begins to resolve stars across the cluster's apparent 6' diameter, but it's evident that a large number of stars contributing to the globular's high overall brightness are just beyond this threshold.

As we advance into Norma and approach the galactic plane, the number of open clusters increases dramatically. One of these is **NGC 5925**, whose 100 stars are loosely scattered across a 15' field. In a region already rich with stars, this object does not stand out well, but it is still recognizable as a cluster in small telescopes and binoculars. Member stars range from 10th through 14th magnitude.

Menzel 1 is one of about 60 known bipolar planetary nebulae in the Milky Way. Its lobes are faint, but it has a bright equatorial ring inclined 45° to our sight line. Telescopically, it looks like a disk 20" in diameter with a hazy edge. A nebula filter helps reveal the ring around a slightly darker central hole.

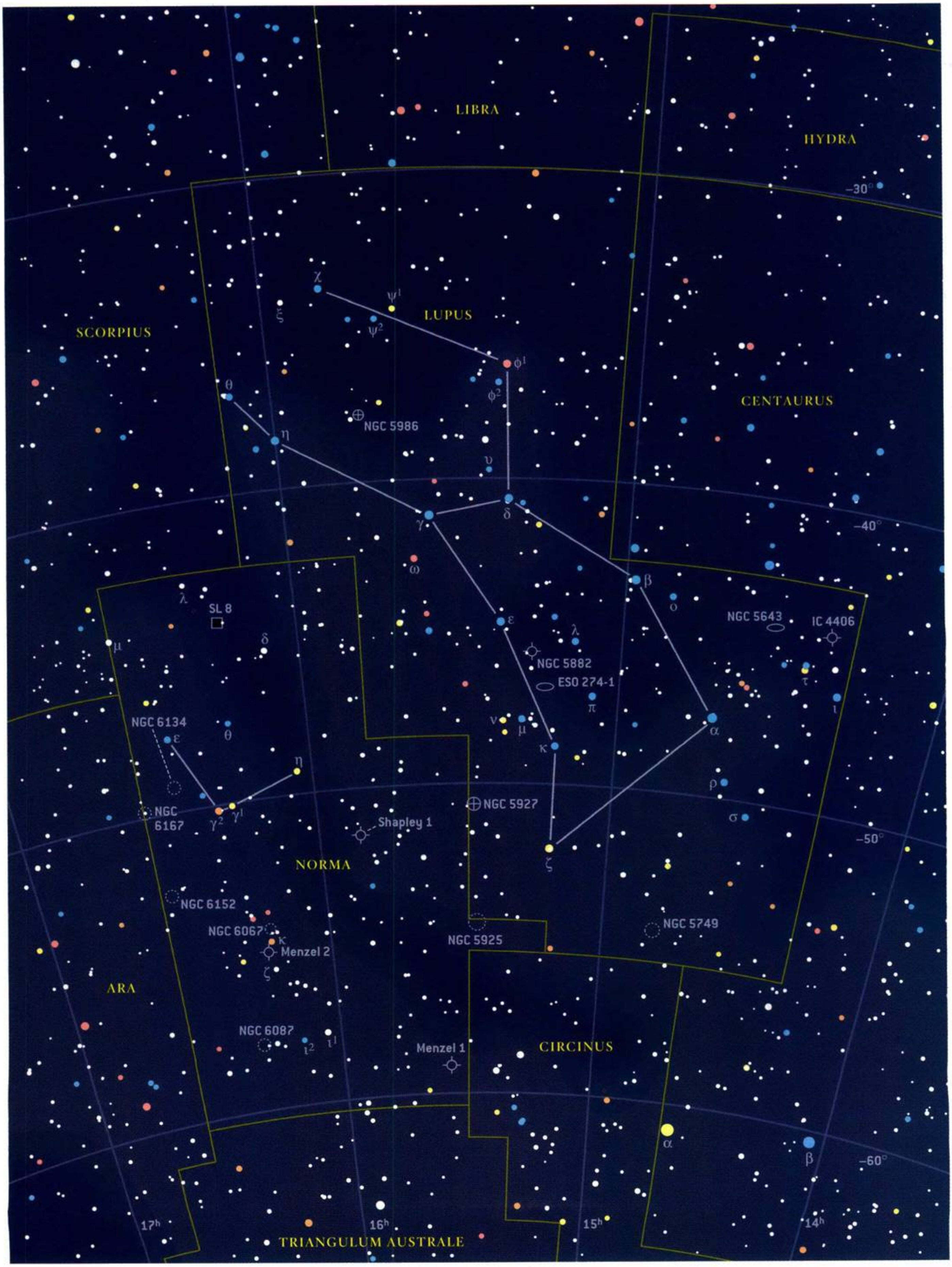
Easily swept up in binoculars, **NGC 6087** contains 40 stars, of which a dozen or so

/// THE WOLF

Midnight is come — is come and gone!
Down on all fours see it plunge and leap!
A human yell in a wolf's howl ends!
What gaunt, gray thing gallops on o'er the world?
Were-wolf, *Julian Hawthorne (1846 – 1934)*

Just as the shape of a wolf is difficult to make out among the stars below Scorpius and Libra, so is the mythology difficult to trace for Lupus. To the east of Centaurus, Lupus has often been represented as an animal impaled on the end of a staff thrust forward by the Centaur. In many European cultures this animal is a wolf, but for others, this constellation has represented beasts such as a boar or a lion.

The constellation Lupus has frequently been associated with the Greek tale of King Lycaon. As ruler of ancient Arcadia with his 50 sons, King Lycaon practiced human sacrifice and cannibalism, which were considered barbaric in other areas of Greece. In one version of the story, the god Zeus disguised himself as a human traveler and visited King Lycaon. When the king offered Zeus a meal containing the flesh of a boy, the god was so angry he killed all of Arcadia's princes with lightning bolts and turned King Lycaon into a wolf. — *Vanessa Thomas*


LIBRA
HYDRA
-30°
SCORPIUS
LUPUS
CENTAURUS
χ
ψ1
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NGC 5986
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NGC 6167
γ2
γ1
NGC 5927
Shapley 1
σ
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NORMA
ζ
NGC 6152
NGC 6067
κ
Menzel 2
ζ
NGC 5925
NGC 5749
ARA
NGC 6087
ι2
ι1
Menzel 1
CIRCINUS
α
β
-60°
17h
16h
15h
14h
TRIANGULUM AUSTRALE

shine at magnitude 9. This sets the cluster apart from the dense fields, but there's no way of telling which of the fainter stars are actually cluster members. Near the center, the brightest star in NGC 6087 is the Cepheid variable S Normae, which was only recently proven to be a member. It has a yellow hue and varies between magnitudes 6.1 and 6.8 over a period of 9.75 days. A faint planetary nebula appears within the cluster's boundaries, but it's actually positioned well behind the cluster.

Lying 5,000 light-years from Earth, **NGC 6067** makes the cut as one of the five most impressive open clusters in the sky. Atop the Norma star cloud, the cluster's setting is already bright with countless stars. It takes a magnificent open cluster to even show up against such a background. NGC 6067 excels, displaying more than 100 stars — most of them between 10th and 13th magnitude — across its 12' diameter. Any instrument works on this open cluster, but a field of at least a half degree will offer the most pleasing view. While small-aperture observing is suitable, large scopes reveal hundreds of stars between magnitudes 14 and 16.

SHAPLEY 1 is a small planetary nebula in Norma. We have a face-on view of the ring of material thrown off by a dying star, now a 14th-magnitude white dwarf at the nebula's center. JACK MARLING

Pan 20' south-southeast of Kappa (κ) Normae to find the planetary nebula **Menzel 2**. Along with Menzel 1, it was discovered by Donald Menzel using the 24-inch Bruce telescope in Arequipa, Peru. A roughly 30" disk with a diffuse edge surrounds a very faint central star. At a distance of 7,000 light-years, the seemingly small disk is nearly one light-year across. A 10-inch telescope begins to show the nebula's hollow center. Seen through larger scopes, there are two dark breaks in the ring 180° apart from each other on the northeastern and southwestern edges.

/// Deep-sky objects in Lupus and Norma

OBJECT	R. A.	DEC.	MAG.	SIZE	TYPE	NOTES
IC 4406	14h22.4m	−44°09'	10.2	106"	PN	—
NGC 5643	14h32.7m	−44°10'	10.4	5.1' by 4.3'	GAL	SAB(rs)c
NGC 5749	14h48.9m	−54°31'	8.8	7'	OC	—
ESO 274-1	15h14.2m	−46°49'	11.7	13.4' by 1.3'	GAL	SAd
NGC 5882	15h16.8m	−45°39'	9.4	7"	PN	—
NGC 5925	15h27.7m	−54°31'	8.4	14'	OC	—
NGC 5927	15h28.0m	−50°40'	8.0	12'	GC	—
Menzel 1	15h34.3m	−59°09'	12.1	26"	PN	ESO 135-11
NGC 5986	15h46.1m	−37°47'	7.5	9.8'	GC	—
Shapley 1	15h51.7m	−51°31'	12.6	76"	PN	—
NGC 6067	16h13.2m	−54°13'	5.6	12'	OC	—
SL 8	16h14.2m	−44°04'	—	25' by 5'	DN	—
Menzel 2	16h14.5m	−54°57'	11.9	27"	PN	ESO 178-15
NGC 6087	16h18.9m	−57°54'	5.4	12.5'	OC	—
NGC 6134	16h27.7m	−49°09'	7.2	8'	OC	—
NGC 6152	16h32.7m	−52°37'	8.1	29'	OC	—
NGC 6167	16h34.4m	−49°46'	6.7	7'	OC	—

Object: Designation in NGC or other catalog. **R. A. and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size:** Size in arcminutes or arcseconds. **Notes:** Hubble types for galaxies.

NGC 6152 is a widely scattered open cluster of 50 stars that is only barely set apart from the Milky Way. It is best seen as a distinct cluster at magnifications below 100x. Near the center are two close but separate clumps of brighter stars.

The sparse open cluster **NGC 6167** lies 3° to the north of NGC 6152. In it, 20 stars form a pattern resembling an H. This arrangement is 4' long and contains mainly 11th- and 12th-magnitude stars. A 7th-magnitude star shines at the western end.

Working north and west, we come upon **NGC 6134**, an open cluster 4,000 light-years from us. Using a magnification of 150x, an 8-inch telescope reveals 50 stars between magnitudes 11 and 14 over an area 5' across. The cluster is well detached from the Milky Way.

Begin at the naked-eye star Delta (δ) Normae and pan 2° northeast to bring in the dark nebula **SL 8**. It is one of 45 dust clouds cataloged by Aage Sandqvist and Peter Lindroos in 1975. An otherwise starry field is punctuated by a starless area nearly one-half degree long and one-fifth as wide. A 7th-magnitude star lies just south of the obscuring cloud's east end. The best views appear in telescopes that show a field at least 2° in diameter.

Our last object is a beautiful planetary nebula that's visible in an 8-inch telescope. **Shapley 1** shows up as a very thin ring 1' in diameter. A nebula filter does wonders to increase the contrast and show Shapley 1's large, central hole. The nebula's ring fades gently at its outer and inner edges. Removing the nebula filter and increasing magnification presents the central star, which glows at 14th magnitude. ◼

PLANETARY OBSERVING

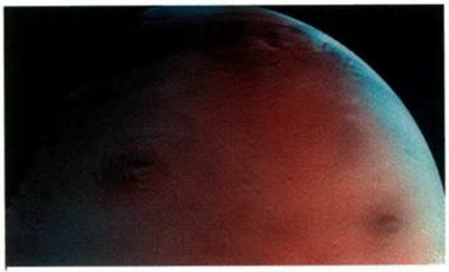
Don't miss the Red Planet's best appearance ever. /// BY MICHAEL E. BAKICH

Get ready for Mars

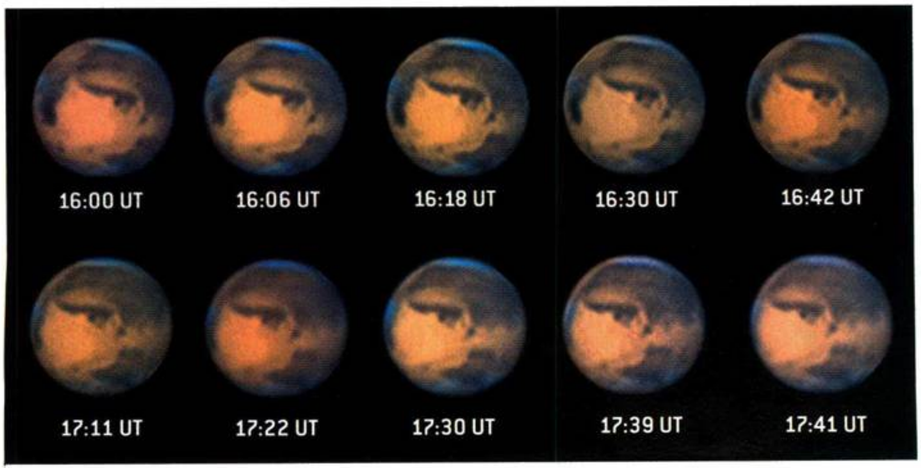
We amateur astronomers enjoy observing Saturn. We love to watch comets. Jupiter and its moons intrigue us. Deep-sky objects thrill us. But Mars? Mars makes us crazy. Observing the Red Planet was once described to me by a friend as "two long years of waiting for four to six weeks of panicked activity." In the case of the opposition of 2003, you could say that it has been 32 years of waiting, ever since the last "great" opposition during the year the first microprocessor was introduced.

Three "great" oppositions of Mars occurred in the 20th century. But the one this month is greater than them all. On August 27, Mars will attain its maximum brightness, possibly reaching magnitude –3.0. The closest approach of Mars to this magnitude was on August 22, 1924. More recently, the Red Planet twice has shone at magnitude –2.9: on September 7, 1956, and on August 12, 1971. The greatest brightness that Mars will attain is always an estimate because Mars is a dynamic place, with ever-changing features like the reflective polar ice caps and the only somewhat predictable dust storms. As a result, the opposition brightness of Mars may differ from prediction by as much as 0.3 magnitude, although recent estimates have been much more accurate.

For those readers new to Mars mania, astronomers' excitement tends to peak during times called oppositions. This is when Mars, in its orbit around the Sun, comes closest to Earth. The word opposition comes from the fact that, as seen in our sky, Mars stands opposite the Sun. This happens every 780 days (minus 1 hour 26 minutes 24 seconds, to be exact). But each closest approach to Earth by Mars is not really, well, closest. You see, the orbits of Earth and Mars are not circular. During a distant opposition, Mars can be more than 60 million miles away. Contrast that with a nearby opposition that places Mars less than 35 million miles from Earth, and you might begin to understand what all the fuss is about.



MARS GLOBAL SURVEYOR recorded this cloudy image of the Red Planet. Two large volcanoes, Olympus Mons (left of center) and Ascraeus Mons (lower right) are seen through northern wintertime haze and water-ice clouds. MOC TEAM, MGS, NASA



THIS FABULOUS SEQUENCE OF MARS was created on the night of the 2001 opposition. Singapore amateur astronomer Tan Wei Leong used a Celestron C11 and an ST7E CCD camera.

It all boils down to apparent diameter. Astronomers use angular measurement to describe how large an object is. With certain objects, mainly planets, the angular size can change a lot. Angular size is part of a circular arc measured in degrees (for large objects), minutes (for smaller objects), and seconds (for tiny objects like planets), or a combination of the above. For example, the distance between two stars may be 14 degrees, 29 arcminutes, 7 arcseconds (denoted 14°29'07"). Mars, on the other hand, varies in size at opposition from a minimum of only 13.8" to a maximum — attained this month — of just 25.1". Unfortunately, the maximum size of Mars is the same as a quarter seen from 650 feet away. And it's that small disk that amateur astronomers are trying to resolve into surface and atmospheric details.

Get started observing Mars

The land area of Mars is approximately equivalent to the dry land area of Earth.

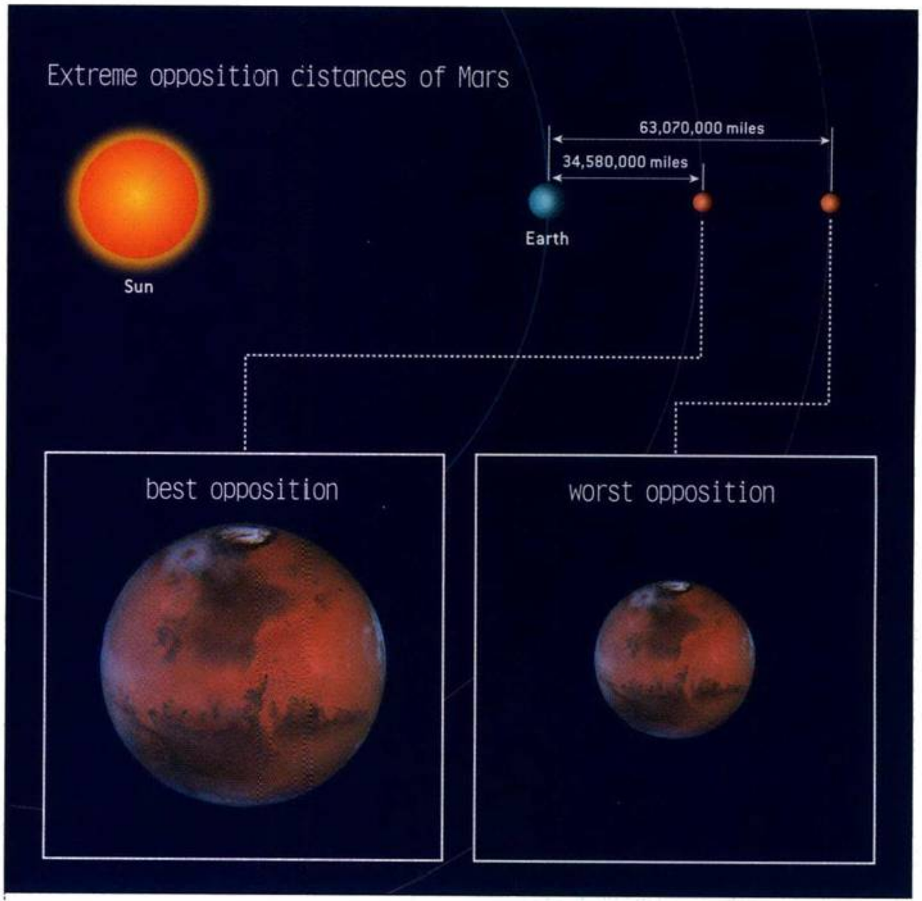
Because Mars is smaller, however, and due to its thinner and more transparent atmosphere and the lack of erosion, what we consider "large" features tend to be more pronounced than those on Earth.

As a longtime (in other words, old) observer of Mars, I have assembled the following Top Ten list of tips to help you get the most out of this — the absolute best — opposition of Mars.

The time is now

Commit a serious amount of time to observing Mars; start on the next clear night. Don't wait for it to reach its opposition diameter before you start observing. High-quality observations have been made even when Mars's apparent diameter was under 10". As long as the atmosphere of Mars is transparent, detail will be visible.

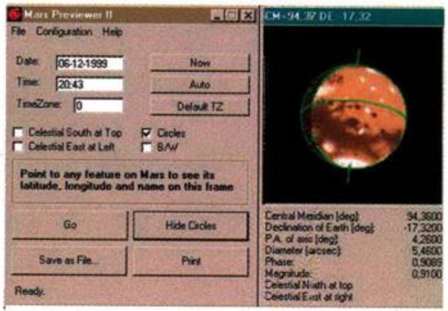
There's another reason not to wait for Mars to reach maximum size, and it's a phenomenon unique to the Red Planet. Oppositions (such as this month's) can occur near the time when Mars is closest to the Sun. At such times, dust storms caused by solar heating rage over huge areas of the planet. If you wait until the date of opposition to observe Mars, there's a fair chance you won't see very much. This occurred during the most recent opposition, in 2001.



THE BEST AND WORST oppositions of Mars are illustrated here. The top diagram shows the distances to scale. The bottom diagram shows the apparent size difference of Mars to scale. This year offers the best possible opposition of Mars. By contrast, the martian opposition of February 25, 1980, was about as bad as it gets. On that date, Mars's diameter was only 13.82". ASTRONOMY: ROEN KELLY

Go to this internet page:

www.astronomysight.com/as/start/books.html and download a copy of a wonderful freeware program (sorry, Windows only) that will help you plan your observations. Leandro Rios of Argentina wrote Mars Previewer II, which displays and identifies the main surface features of Mars at any given date and time. It is very easy to use, and I highly recommend it.



Date: 06-12-1999
Time: 20:43
TimeZone: 0

☐ Celestial South at Top ☑ Circles
☐ Celestial East at Left ☐ B/W

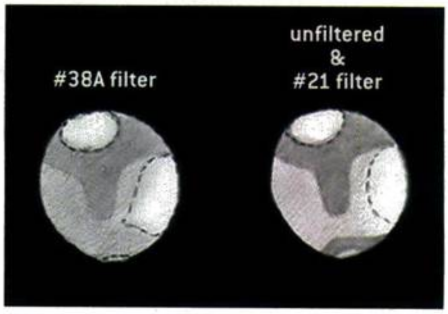
Point to any feature on Mars to see its latitude, longitude and name on this frame

Ready.

CM -94.37 DE -17.32

Central Meridian [deg]: 94.3600
Declination of Earth [deg]: -17.3200
P.A. of axis [deg]: 4.2600
Diameter [arcsec]: 5.4600
Phase: 0.9089
Magnitude: 0.9100
Celestial North at top
Celestial East at right

MARS PREVIEWER II is excellent, easy-to-use software that identifies martian features visible at any time.



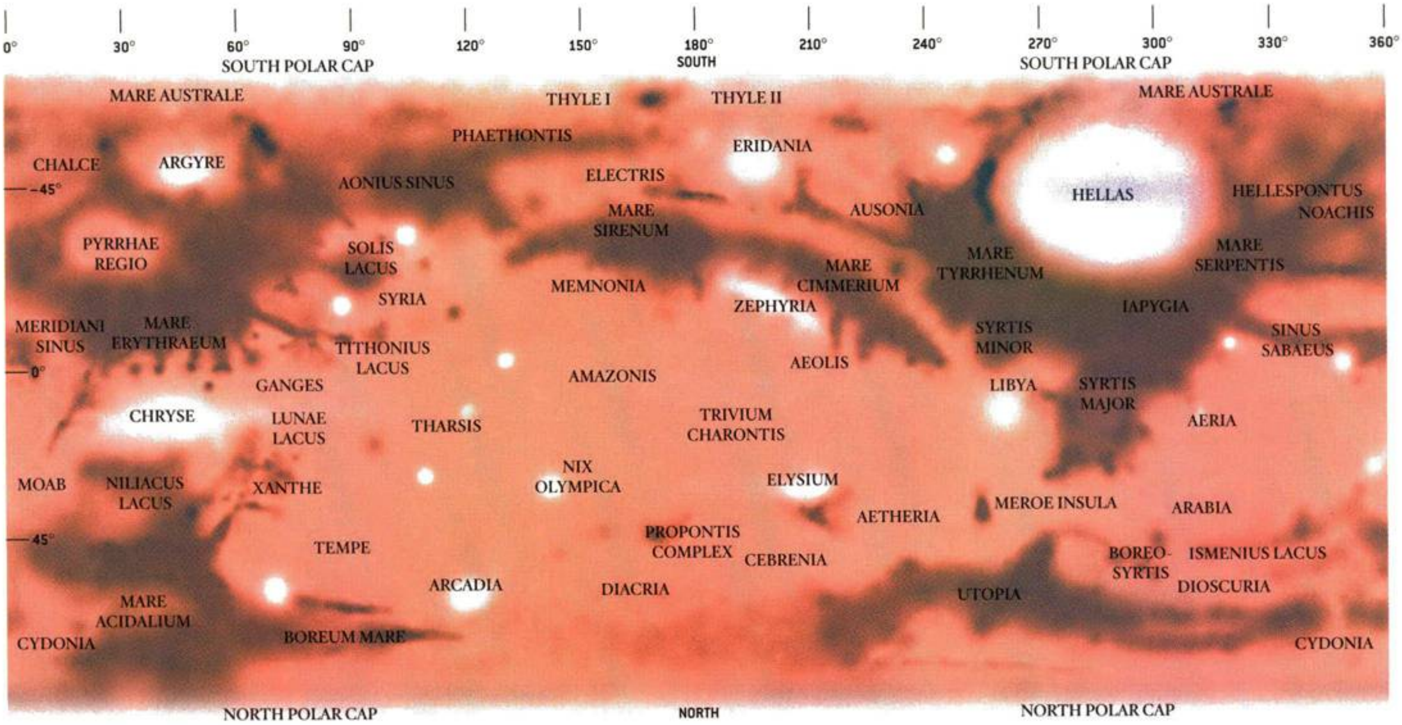
WHEN MARS APPEARS SMALL, detail can still be seen. This pair of sketches by Damian Peach of Tenerife, Spain, was made on February 14, 2001, using a Meade 12-inch SCT when Mars was only 6.93" in apparent size. The large, dark albedo feature, Syrtis Major, is more apparent when viewed unfiltered or through a #21 orange filter (right) than through a #38 dark blue filter.

Know the numbers of Mars

Mars's day (which, by the way, is known as a sol) is 37.4 minutes longer than a day on Earth. So, if you observe Mars at the same time each night, its markings will move (37.4/1477.4) x 360° = 9.11°/day to the west. In a little more than five weeks, the Red Planet will seem to slowly rotate backward one full spin. All the prominent features of Mars (see the albedo map on page 82) will be, at some time during this period, placed favorably on its meridian.

You can also wait for Mars's rotation to bring an albedo feature into view, or onto its meridian. Because Mars rotates once every 24.623 hours, in one hour it rotates 360°/24.623 = 14.62°. So, for example, say you are observing Libya (longitude = 260°) on the martian meridian, and you want to know when Iapygia (longitude = 295°) will cross the meridian later that same night. Divide 35° (their separation in longitude) by 14.62°/hour = 2.4 hours. This is the time between meridian crossings of the two features.

Mars got its system of longitude in 1868. In that year, British astronomy popularizer Richard A. Proctor (1837–1888) published *The Lands and Seas of Mars, from 27 Drawings by Mr. Dawes.* This was a record of observations of Mars conducted by William Rutter Dawes (1799–1868)


0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
360°
SOUTH POLAR CAP
SOUTH
SOUTH POLAR CAP
MARE AUSTRALE
THYLE I
THYLE II
MARE AUSTRALE
PHAETHONTIS
ERIDANIA
CHALCE
ARGYRE
-45°
AONIUS SINUS
ELECTRIS
HELLAS
HELLESPONTUS
NOACHIS
MARE SIRENUM
AUSONIA
PYRRHAE REGIO
SOLIS LACUS
MARE TYRRHENUM
MARE SERPENTIS
MARE CIMMERIUM
MEMNONIA
SYRIA
ZEPHYRIA
IAPYGIA
MERIDIANI SINUS
MARE ERYTHRAEUM
SYRTIS MINOR
SINUS SABAEUS
TITHONIUS LACUS
0°
AEOLIS
AMAZONIS
GANGES
LIBYA
SYRTIS MAJOR
CHRYSE
LUNAE LACUS
THARSIS
TRIVIUM CHARONTIS
AERIA
NIX OLYMPICA
MOAB
NILIACUS LACUS
XANTHE
ELYSIUM
MEROE INSULA
ARABIA
AETHERIA
45°
TEMPE
PROPONTIS COMPLEX
CEBRENIA
BOREO-SYRTIS
ISMENIUS LACUS
ARCADIA
DIACRIA
UTOPIA
DIOSCURIA
MARE ACIDALIUM
BOREUM MARE
CYDONIA
CYDONIA
NORTH POLAR CAP
NORTH
NORTH POLAR CAP

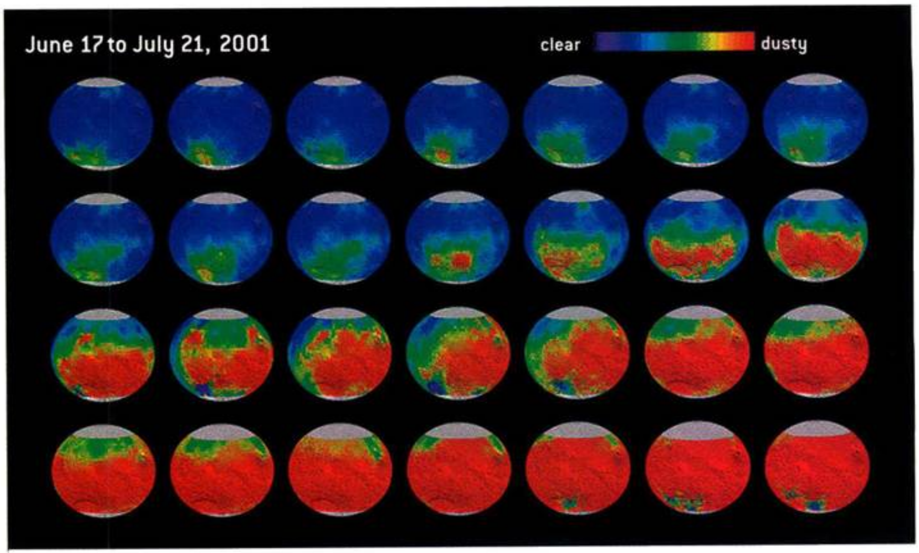
MARTIAN ALBEDO FEATURES are observable markings on the surface of the Red Planet. Their visibility changes based on the percentage of sunlight they reflect (called the albedo). In addition to watching the prominent dark markings, keep an eye on Hellas, the large, light area near 300° longitude and 45° south latitude. This is where localized dust storms often begin. South is up, so this map matches the view through a telescope. ASTRONOMY: ROEN KELLY

from 1852 to 1865. Proctor chose a spot for zero longitude on the Red Planet that survives to this day. His selection corresponds to the crater Airy-0, which is found in Sinus Meridiani.

Know the landscape of Mars

The most prominent surface features on Mars are the polar ice caps. Due to the wide temperature range, each of the ice caps can be subdivided into larger "seasonal" and smaller "residual" caps. The southern residual ice cap is approximately 200 miles in diameter and is composed of frozen carbon dioxide (CO_2). The northern residual ice cap is composed of water ice and is larger, having a diameter of about 600 miles. Both seasonal ice caps are composed of frozen CO_2, which condenses directly from the atmosphere when the temperature is below –190° F. Winters are more severe in the northern hemisphere, and the ice cap there has been known to reach a latitude of 45°. In the southern hemisphere the seasonal ice cap never passes above a latitude of about –55°.

Apart from the polar ice caps, the easiest feature for observers to identify on Mars is the dark, roughly triangular albedo feature named Syrtis Major. An albedo feature is a region distinguished by the amount of light reflected from it. Albedo features are also the areas most subject to seasonal changes. For example, when I first started observing Mars, Syrtis Major noticeably grew as the martian summer approached its location and then shrank. For the last decade, though, its size has been quite constant.



A PLANET-WIDE DUST STORM gripped Mars after perihelion passage in 2001. These observations from the orbiting Mars Global Surveyor (MGS) spacecraft illustrate the storm's progress as measured by the MGS Thermal Emission Spectrometer, which can determine both temperature and amount of atmospheric dust. Blue represents relatively clear atmosphere, and red indicates increasing concentrations of dust. TES TEAM/MGS/JPL/NASA

Other favorite albedo features for observers are Chryse, Elysium, Hellas, Libya, and Solis Lacus. But, honestly, dedicated Mars observers look for as many features as are visible and so should you. Later, you can compare your observations with those from previous sessions. Some observers like to "pair up" features of similar brightness early during a Mars observing season and then compare those features to each other as opposition approaches. If done once a week or so, changes can be noticed more quickly.

Know the sky of Mars

All martian clouds are temporary phenomena, and several different types are observable. Seasonal clouds are related to the heating and cooling that causes sublimation and condensation. Discrete clouds are usually associated with a specific area, and they are carried along as the planet rotates. Most discrete clouds are found in Mars's northern hemisphere during the spring and summer.

Certain discrete clouds are known as orographic clouds. Wind passing over the high peaks of martian mountains and volcanoes creates these clouds, which are at high altitudes and are composed of water. When trying to observe orographic clouds, a blue or (if your scope is large enough) violet filter generally works best.

If you have access to a high-quality medium-size telescope, I offer the following observing challenge: Try to observe the Syrtis Blue Cloud of Mars. This is a very famous discrete cloud associated with the Libya basin and Syrtis Major. It was first observed in 1858 by the Italian astronomer Angelo Secchi (1818–1878). Viewed without a filter, this cloud turns Syrtis Major a bluish color, so a yellow filter will tint the portion of Syrtis Major covered by the cloud green.

Moving away from Mars's central meridian, morning and evening clouds may also be observed. These are bright, isolated patches of surface fog seen at sunrise (the western edge of Mars) or sunset. Ground frost, which appears similar to fog, might also be seen. The difference between fog and frost can be distinguished in an hour or so, after which the fog usually dissipates. Frost may last all day. Evening clouds are generally larger and more numerous, and as the martian night approaches, they get even bigger. Your chances of seeing these clouds are better if you use a blue or violet filter.

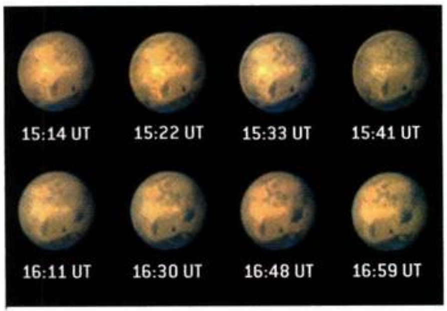
Finally, we come to martian dust storms, which, I suppose, could be considered a combination of the landscape and the sky. These appear bright when viewed through a yellow filter. They are interesting, however, only when they are localized dust storms associated with a specific desert region. Global dust storms that blanket the surface of Mars turn exuberant observers into sad complainers. Dust storms are more likely to occur near martian perihelion, but can occur anytime. Summertime dust storms are generally the largest and have greater coverage. Global dust storms were unknown until 1956. Since then, six have been seen, including the most recent one in 2001.

Crank up the power

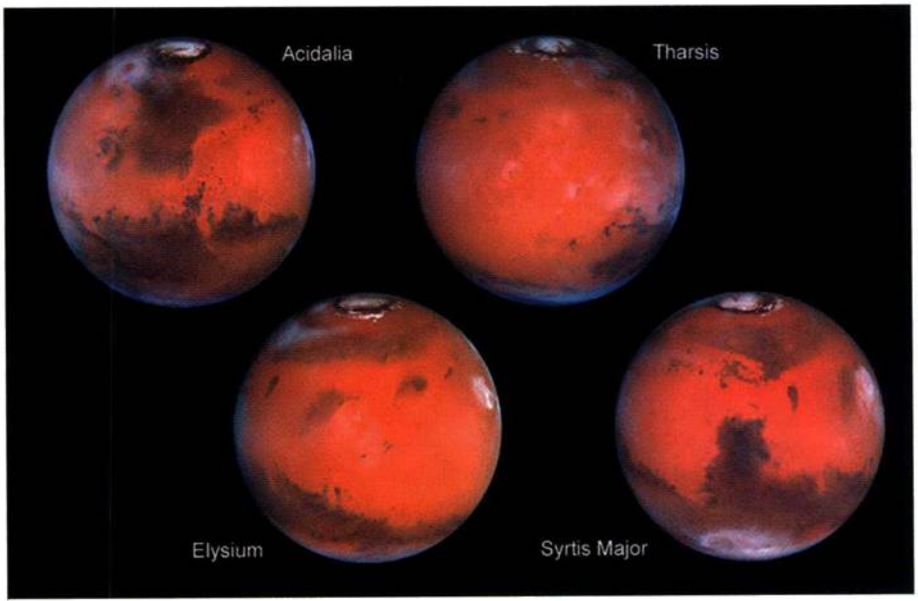
Great observers use many eyepieces, but unlike not-so-great observers, they use high magnification. Mars, due to its small size, cries out for short focal length eyepieces or Barlow lenses (or both!). It's essential that you increase magnification

CLOUDS ABOVE THARSIS, a huge, uplifted region on Mars containing three giant volcanoes, are seen in this Mars Global Surveyor image. MOC TEAM/MGS/NASA

SMALL TELESCOPES	MEDIUM TELESCOPES	LARGE TELESCOPES
#8 Light Yellow 83% transmission is somewhat useful for increasing contrast between light and dark areas in the smallest of apertures	**#21 Orange** 46% transmission increases contrast between features more than #15; penetrates hazes; allows some detection of dust clouds	**#25 Red** 24% transmission gives maximum contrast of surface features; enhances fine surface details, dust cloud boundaries, and polar cap boundaries
#12 Yellow 74% transmission brightens desert regions, darkens bluish and brownish features	**#23A Light Red** 25% transmission increases contrast between details and assists in the identification of dust clouds slightly more than #21	**#38A Dark Blue** 17% transmission shows atmospheric clouds, discrete white clouds, limb hazes, and polar cloud hoods; darkens reddish features
#15 Deep Yellow 67% transmission increases the contrast of dark areas with the background more than the two filters mentioned above	**#56 Light Green** 53% transmission brings out limb hazes, terminator clouds, and frost patches; great filter for polar caps	**#47 Violet** 3% transmission shows all the features of #38A to a greater degree
#82A Light Blue 73% transmission helps with clouds, frost, and polar caps; allows much more light through than #80A	**#80A Blue** 30% transmission enhances all clouds and ground frost along with polar caps; darkens reddish features	**#58 Green** 24% transmission darkens red and blue features; enhances frost patches, surface fogs, and polar caps to a greater extent than #56



MINIMAL SURFACE DETAIL, as seen here, is sometimes caused by martian global dust storms. Tan Wei Leong of Singapore took this set of images through a Celestron 11-inch SCT and an ST7E CCD camera on July 1, 2001, less than two weeks after opposition.



THIS HUBBLE SPACE TELESCOPE QUARTET taken near the 2001 opposition shows many albedo features on Mars. Compare these images to the albedo map on page 82. These are "non-telescopic" views, so north is up. S. LEE (UNIV. OF COLORADO), J. BELL (CORNELL UNIV.), M. WOLFF (SPACE SCIENCE INSTITUTE), AND NASA

right up to the limit of the night's seeing. There's a lot of detail on Mars, so why not give yourself the best chance at it? When moments of good seeing do arrive, concentrate your attention on a small area or a single feature. Trying to view the entire disk all at once or darting your gaze from one feature to another is not a profitable use of your observing time. Compare your views to this article's albedo map of Mars, or use Mars Previewer II as noted earlier.

Take advantage of filters

Filters are either feared or misunderstood by beginning amateur astronomers who don't fully understand what the filter should show or who find the view very unappealing. If you fall into this last category, you're not alone. Color filters do have a purpose; however, it's not making an object "pretty." The purpose is to exaggerate differences in brightness. When I hear someone speak ill of color filters, it indicates to me that he or she was looking for changes in color rather than changes in brightness.

> Commit a serious amount of time to observing Mars; start on the next clear night. Don't wait for it to reach opposition before you start observing.

Color filters are labeled along their circumference and are usually screwed into the eyepiece barrel. In some cases, observers prefer to hand-hold the filter and move it back and forth between the eyepiece exit lens and their eye. The purpose of such a maneuver is to quickly compare the filtered view with the unfiltered one. Be aware that filters have been dropped and broken like this, especially in cold weather when the observer was wearing gloves. Certain manufacturers also make filter holders. Such units allow up to four filters to be used simultaneously. Most of the amateurs I know who use such a device leave one filter slot empty so they can also study the unfiltered view.

Most color filters work better when used with larger telescopes. It's a simple rule of light throughput. For example, my 4-inch refractor will not show cloud features on Venus (or much else!) when I use a #47 violet filter (3% transmission). It just doesn't work. However, using a 12-inch SCT, features are easily seen through the same filter. For more information about color filters, see "Filtering the sky," beginning on page 86.

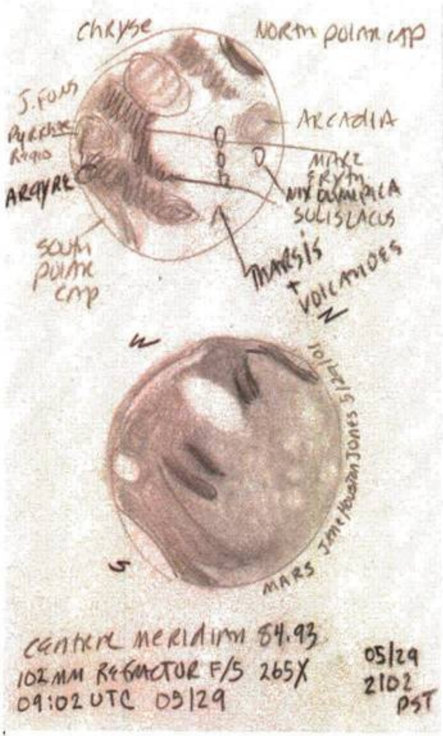
Sketch the Red Planet

The first sketch of Mars was made by Dutch astronomer Christiaan Huygens (1629–1695), on October 13, 1659. Some 48 days later, on November 28, Huygens recorded the first observation of a feature on Mars; it was almost certainly Syrtis Major. For today's amateur astronomers on limited budgets, sketching is the great equalizer. You may not have a CCD camera, but odds are good that you have a pencil and some paper.

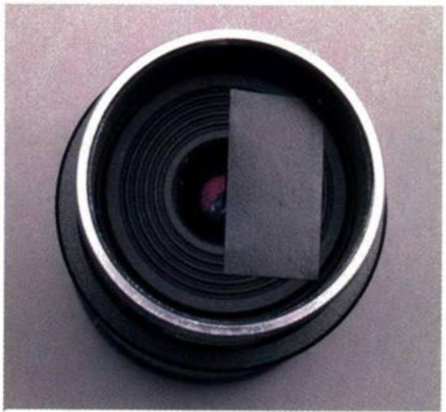
When sketching Mars, start with the polar ice caps, if they're visible. How close to the equator do their edges come? This is a great starting point, and if you're careful here it will aid tremendously in positioning other features on your sketch. Next, trace the most prominent dark features you see. Finally, lightly fill in the finer details. For your initial sketches, use a black pencil. Later, you might wish to explore the use of color.

Take your time. Most sketches require 15 to 30 minutes to complete. The more you sketch, the faster you'll get. Keep in mind that Mars rotates only 14.62° per hour, so you'll have plenty of time to work on the features you see. By compelling you to be patient, sketching will make you a better observer faster than any other activity. While you're sketching, you will come to understand the advantage of good seeing: Features will seem to magically appear as the part of Earth's atmosphere between you and Mars momentarily steadies.

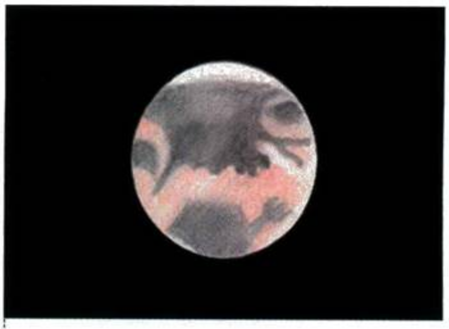
Let me suggest a project. Although individual sketches are nice, think about



THIS EXCELLENT SKETCH OF MARS was made by Jane Houston Jones, a member of the San Francisco Sidewalk Astronomers, on May 29, 2001. This example demonstrates sketching and recording log book-type details with a second, explanatory sketch.



AN OCCULTING BAR, in its simplest form, is made by placing a piece of opaque tape over the field stop of an eyepiece. WILLIAM ZUBACK



MANY DETAILS ARE APPARENT in this color sketch of Mars made by Damian Peach on May 22, 2001, looking through a Meade 12-inch SCT. Mr. Peach combined an unfiltered view and one through a #25 red filter to capture Mars when its apparent size was 17.77".

making a number of them over time, say from now to one month past opposition. Such a series may show differences in seasonal clouds, changes in the polar ice caps, or even the development of dust storms.

For today's amateur astronomers, sketching is the great equalizer. You may not have a CCD camera, but odds are that you have a pencil and some paper.

Note to beginners

Don't do what I did and start your sketching career by making huge circles. I began with 8" diameter circles printed from my computer. They were so nice and neat — but that's a lot of area to fill, and it took what seemed like forever to do just one sketch. So start conservatively (2" to 3") and go larger later, if you wish.

Unfortunately, a circle works only when Mars is near opposition. Several months on either side of opposition, Mars shows a distinct gibbous phase, and you will want your sketches to reflect that. Maximum phase occurs when Mars is 89% illuminated. An 11% difference may not sound like much, but at the eyepiece it's very noticeable. This is approximately the difference between a Full Moon and a Gibbous Moon three days from full.

Observe Phobos and Deimos

Do you need an observing challenge this year? The tiny moons of Mars are within reach of many amateur telescopes, including 8-inch SCTs. Phobos hovers around 11th magnitude two weeks on either side of opposition, and Deimos is a magnitude fainter. Objects at these magnitudes don't sound that difficult to observe until you factor in the brilliance of Mars. At magnitude –3 (a real possibility), Mars is on the order of four hundred thousand times brighter than Phobos and a million times brighter than Deimos. Believe it or not, Deimos is the easier moon to spot because of the greater angular separation it can attain from Mars.

Near opposition, Phobos will be separated from the center of Mars's disk by a maximum of 34.6". This means it will be 22.1" from the edge of the planet during an event called greatest elongation. Greatest elongation of each moon can be either east or west of Mars. When Deimos reaches greatest elongation, it will be farther away — 74.1" from the edge. But how are you to know when these moons will attain their maximum separations and thus be easier to see? Some software packages like Starry Night Pro do a good job of showing the correct orientation of Mars and its moons. On the Internet, visit Mark Showalter's Martian Moon Tracker page: ringmaster.arc.nasa.gov/tools/tracker2_mar.html

When attempting an observation of Phobos and/or Deimos, remember that these faint satellites cannot be seen if Mars is also in the field of view. Viewing them requires either that you place Mars outside the field or that you use an occulting bar (see the center illustration above). More experienced observers might wish to identify and locate two stars with magnitudes similar to the martian moons, using each as a gauge of brightness.

Keep a log

Whether you observe visually or make sketches or images with a camera or CCD, keeping a record of your observations is one of the most important tips I can give you. How many details should you include? That's up to you. The basics are date and time, telescope and eyepiece, and sky conditions. For quick future reference, many Mars observers often list the longitude of the central meridian, the size of the planet at the time of their observation, and the magnification of the eyepiece.

This summer will offer the biggest Mars we have ever seen. Let's hope it's also the best. Good luck! ■

TECHNIQUES

Learn how to use color filters to bring out subtle details when you view planets. /// BY PHIL HARRINGTON

Filtering the sky

Good optics, a discerning eye, and a clear, steady sky are critical for seeing fine planetary details. The most important aspect, and the easiest to control, is optical quality. Unless both your telescope and your eyepieces have excellent optics, trying to spot delicate features on a planet will be difficult, even under perfect skies.

To get the most out of these three tandem-working parts, most seasoned observers agree that color filters can significantly enhance hard-to-see details on the Moon, planets, and other celestial objects. They do this by increasing or reducing the contrast between features. Filters enhance subtle differences between adjacent regions on a planet or the Moon by transmitting (keeping visible) one color while absorbing (blocking) others. Some even help reduce distortion caused by Earth's atmosphere, which can make contrast distinctions difficult to see.

Celestron International
2835 Columbia Street
Torrance, CA 90503
[t] 310.328.9560
[w] www.celestron.com

Meade Instruments
6001 Oak Canyon
Irvine, CA 92620
[t] 800.626.3233; 949.451.1450
[w] www.meade.com

Orion Telescopes & Binoculars
P.O. Box 1815
Santa Cruz, CA 95061
[t] 800.447.1001; 831.763.7000
[w] www.telescope.com

VERNONscope
151 Court Street
Binghamton, NY 13901
[t] 888.303.3526; 607.722.5697
[w] www.vernonscope.com

Making choices

Choosing the right filter for a target requires a little knowledge of the target itself. For instance, because Mars is predominantly red, a red filter will accentuate the planet's ruddy deserts, while darkening its greenish regions. Viewing Mars through a green filter will have the opposite effect.

Filters usually screw into the barrel of an eyepiece. With few exceptions, all eyepiece barrels have standard threads machined into them. This means you can use a filter from company A in an eyepiece made by company B. Of course, you'll need to select the filter based on the diameter of your eyepiece barrel — 1¼" filters for 1¼" eyepieces, and so on. Most filter cells are also threaded to accept other filters, enabling observers to "stack" one filter on top of another. The combined color and its effect on a target will be quite a bit different than if either filter was used alone. Depending on the combination, the image also may be quite dim.

The commonly used Wratten series of color filters, created by Eastman Kodak for the photographic industry, contains more than 100 different hues and densities. To prevent confusion, they're often referred to by their number instead of their color. Today, calling out a Wratten number is the standard way of referring to a filter's color or, more precisely, to the spread of wavelengths it transmits.

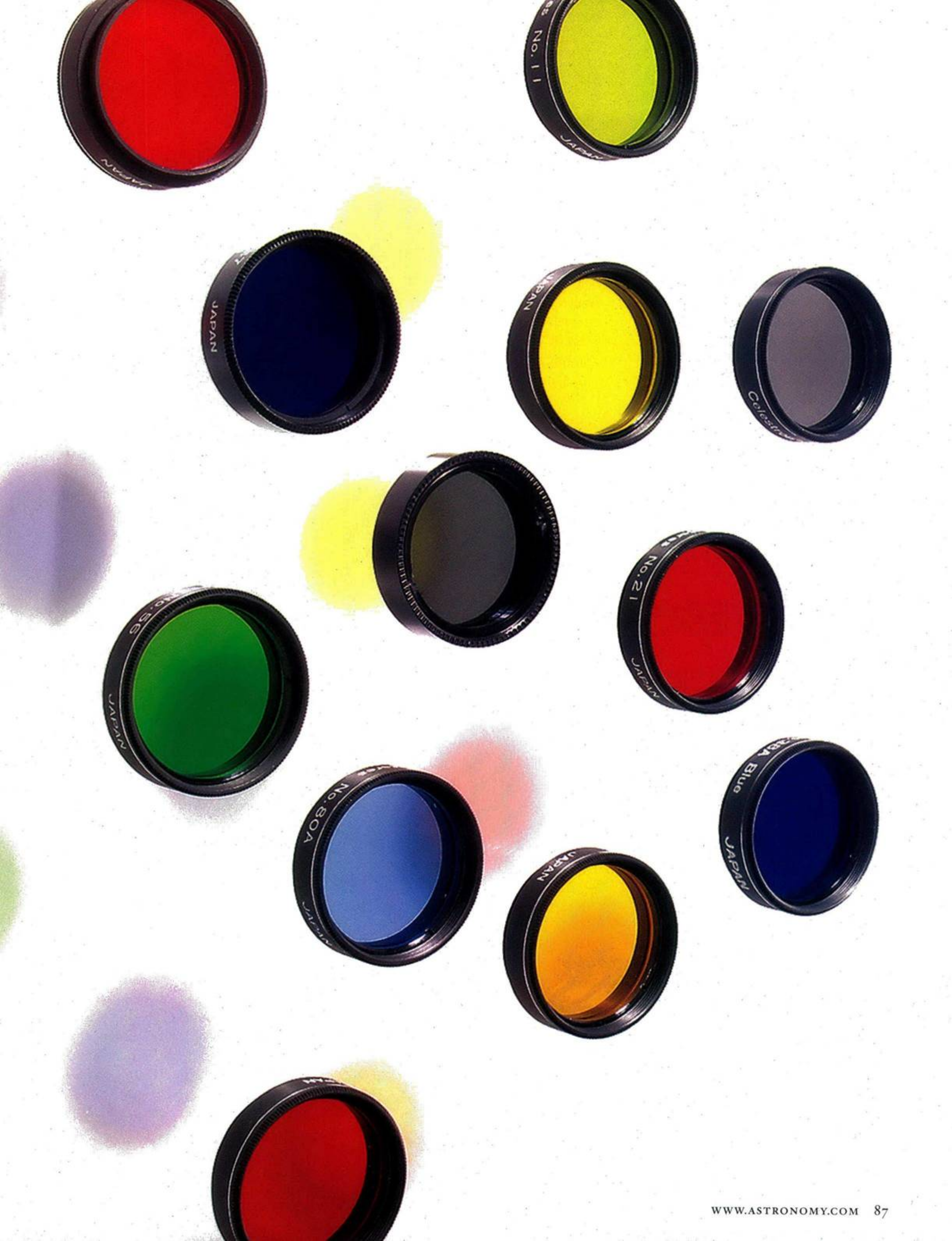
You certainly don't need dozens of separate filters to enjoy the benefits of filtered observing. In fact, many experienced amateurs use four to eight filters. But that raises the question: Which filters should I use? The answer depends on the celestial object you select, the effect you're looking for, and what size scope you have. Here's a quick breakdown of filters that provide the best views of different sky objects.

The Moon

When pointing toward the Moon, many amateur astronomers reach for a neutral density (ND) filter. These filters dim the Moon's appearance evenly across the visible spectrum. Like sunglasses, they cut down on the bright glare of moonlight streaming into an eyepiece. The transmission of a neutral-density filter is designated by a numerical grade. For example, a filter graded "ND 0.1" transmits 80% of the light, while an ND 1.0 filter transmits only 10%. Most Moon filters transmit 13% to 18% of the light striking them.

Some observers prefer using variable polarizing filters instead. Variable polarizers, which have a transmission range between 5% and 30%, can be adjusted to dim or brighten the Moon's appearance.

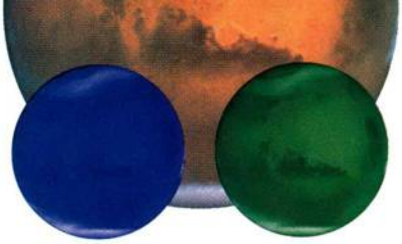
Although both filter styles make observing bright lunar phases more comfortable, they do little to enhance surface features. For added contrast, many confirmed "lunatics" use a deep yellow (Wratten 15, abbreviated W15) or pale blue (W82A) filter. If you are viewing with an 8-inch or larger telescope, try a green (W58) filter, which increases contrast while diminishing the Moon's intensity. Of course, it will do little to dispel the notion that the Moon is made of green cheese.



No. 11
JAPAN
JAPAN
JAPAN
Celestron
No. 21
JAPAN
No. 56
JAPAN
No. 80A
JAPAN
JAPAN
38A Blue
JAPAN

JUPITER'S BANDS DIVIDE when enhanced with yellow-green (W11) or orange (W21) color filters.

BEST SEEN FILTERED through yellow (W15) or pale blue (W82A), the Moon comes alive when filters increase feature contrast.



WHEN LOOKING FOR DUST ON MARS, switch between blue (W38) and red (W25) color filters. Use a green (W58) filter to search for ice.

Mercury

The toughest part of observing the innermost planet is simply finding it against the twilight sky. To help pick out Mercury, try a red (W23A or W25) filter. Both of these filters darken the sky, helping to isolate Mercury from its surroundings.

As an inferior planet, Mercury goes through phases just like Venus. Observing these phases is a significant challenge because Mercury's tiny disk requires at least 150x to appear as anything more than a point of light. Its low altitude above the horizon also traps it in the muck of air pollution, turbulence, and clouds. Some observers have luck isolating the planet's phase by using an orange (W21) or a light blue (W80A) filter.

Venus

Like the Moon, Venus's sheer brilliance can easily overwhelm your eye, especially if the planet is observed through a 6-inch or larger telescope. Many find that a red (W25) or violet (W47) filter darkens the background sky as well as reduces glare to more manageable levels. A light blue (W80A) filter also helps when viewing Venus against heavy twilight, while an orange (W21) filter darkens the blue sky for observing Venus during daylight.

Unfortunately, no filter will cut through the planet's obscuring atmosphere, although some observers have recorded apparent irregularities in venusian clouds when using yellow (W12), green (W58), and violet (W47) filters.

/// SORTING THROUGH COLOR FILTERS

Company/Model	Colors/shades or % transmission	Diameter	Comments
Celestron International			
Color filters	12 colors/shades	1¼"	26mm clear aperture; available in sets
Moon filter	18% transmission	1¼"	21mm clear aperture
Neutral density filters	Three densities	1¼"	
#94118-17 polarizer		1¼"	
#93608 variable polarizer	5% – 30% transmission	1¼"	
Meade Instruments			
Series 4000	12 colors/shades	1¼"	26mm clear aperture
Series 4000 Moon filter	13% transmission	1¼"	26mm clear aperture; ND 0.9
#905 variable polarizer	5% – 25% transmission	1¼"	
Orion Telescopes & Binoculars			
Color filters	12 colors/shades	1¼", 2"	Sold only in sets
Moon filter	13% transmission	1¼"	ND 0.9
Variable polarizer	3% – 40% transmission	1¼"	
VERNONscope			
Color filters	13 colors/shades	1¼"	25mm clear aperture; non-standard thread*
Polarizer	30% transmission	1¼"	25mm clear aperture; non-standard thread*

**Note: VERNONscope filters are threaded to fit VERNONscope brand eyepieces only. An adapter to fit these filters to other, standard-thread eyepieces is sold separately.*

Mars

Even at its best, as it is this summer, Mars only measures 25" across, half the size of Jupiter. A few good color filters will go a long way toward bringing out the best that Mars has to offer.

If you own a 4-inch or smaller telescope, your best friend for viewing Mars is an orange (W21) filter. It will darken the martian albedo features, while making the surrounding desert regions stand out. Telescopes with 4-inch to 10-inch apertures will enjoy the same benefit using a light red (W23A) filter, while the largest backyard scopes should use a red (W25) filter. All three filters help penetrate martian haze and clouds.

Other colors can be used to enhance additional features. For instance, a green (W58) filter brings out the frost patches and melt lines around the polar caps.

The Association of Lunar and Planetary Observers (ALPO) cautions that many old reference books, which recommend using yellow (W12 or W15) filters for detecting martian dust storms, are obsolete. While yellow filters are sensitive to dust storms, so much of Mars appears bright through yellow filters that the dust is masked. Instead, look along the martian limb while switching between red and blue filters. If a cloud appears bright in a red filter, but dim in a blue one, chances are you're seeing a dust cloud. The feature enhancement will be just the opposite if you're looking at an ice cloud. Try a light blue (W80A) filter for 4-inch and smaller telescopes and a deep blue (W38) for larger instruments.

I also have found that narrowband light-pollution filters (such as Orion's UltraBlock or Meade's 908N) often improve the view of Mars (and Jupiter), making these filters more versatile than many realize. If you already have one in your accessory case, give it a try.

Phil Harrington's *next book,* Star Watch, *will be available from John Wiley & Sons this summer. Visit www.philharrington.net for more details.*

Jupiter

The many delicate gradations found within Jupiter's multi-banded atmosphere offer the perfect proving ground for color filters. While only Jupiter's north and south equatorial belts stand out well without filters, six or more additional jovian bands can be seen through various color filters.

Since many of Jupiter's clouds are white, beige, or yellowish, an orange (W21) filter helps accentuate the delicate loops and festoons that swirl within and between different belts and zones. A yellow-green (W11) filter brings out finer structures within the jovian cloud tops. Orange belts, white ovals, as well as the elusive Great Red Spot (which is more of a pink or salmon color) all do well with light green (W56), green (W58), and light blue (W80A) filters. These colors darken the features against the planet's ivory background.

Like Venus, Jupiter shines so brightly that its glare can easily overwhelm the eye. To counter that, try using a neutral-density filter. Determining which filter will work best depends on telescope aperture. For 8-inch and larger instruments, one that transmits between 25% and 50% of the light striking it (referred to as ND 0.6 and ND 0.3, respectively) is recommended.

Saturn

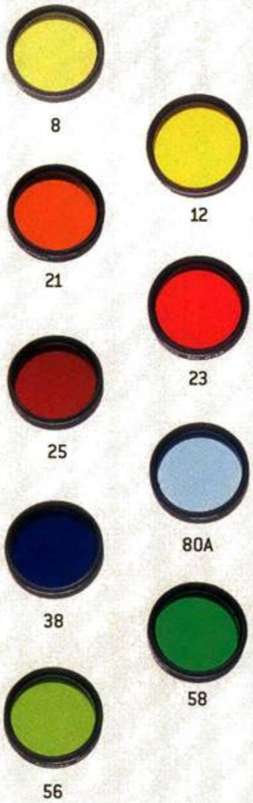
Saturn's more subtle shadings are accentuated with the same color filters used for Jupiter, although results are not quite as dramatic. Yellow (W12) and orange (W21) filters enhance the soft contrasts in Saturn's atmosphere and improve the visibility of the Cassini Division within the icy ring system.

Light blue (W80A) and green (W58) filters help amplify atmospheric contrast by darkening different regions, while a light red (W23A) or red (W25) filter will accentuate polar regions and any bluish features within the saturnian atmosphere.

Uranus and Neptune

Since both of these distant worlds are extremely faint, color filters may only make them more difficult to see. The use of filters with telescopes smaller than about 10 inches in aperture isn't advised when searching for Uranus and Neptune. For amateurs with double-digit apertures, yellow (W8 or W12) filters can help bring out some vague details in each planet's pastel atmosphere.

/// FILTER SPECIFICATIONS



Wratten number	Color	Percentage of light transmitted
8	Light yellow	83
11	Yellow-green	78
12	Yellow	74
15	Deep yellow	67
21	Orange	46
23 A	Light red	25
25	Red	14
38	Deep blue	17
47	Violet	3
56	Light green	53
58	Green	24
80 A	Light blue	30
82 A	Pale blue	73

The percentage of light transmitted by a filter is related to the range of wavelengths it transmits and the amount of blocking it does at other wavelengths. In general, deep filters transmit a narrower range of wavelengths than lighter filters and completely block light from wavelengths outside that range.

Comets

Comets are funny creatures. Some look much better through color filters, while others may look worse. Light blue (W80A) filters can increase the contrast in the gas tails of some comets, while light yellow (W8), yellow (W12), and orange (W21) filters can enhance dust tails. The next time a comet passes through the sky, give these filters a try.

Recommendations

Although photographic Wratten filters are available at better camera stores, filters made specifically to screw into eyepieces are preferred. The table on page 86 lists some retailers of astronomical filters.

Be sure to check that your eyepieces and filters have the same thread size, or they won't screw together. Fortunately, the vast majority do. Also, if you're going to buy a variable polarizing filter, be aware that some designs require the eyepiece to slide into a holder that sticks out of the focuser, like a Barlow lens. As a result, some eyepieces will not focus properly if the telescope's focuser has limited travel.

But which should you buy? Start out by choosing four or five basic colors, such as yellow (W12 or W15), orange (W21), red (W23A or W25), green (W58), and light blue (W80A). Later, add more to suit your own interests. For instance, with Mars at optimum viewing, a deep blue (W38) filter might make a nice addition. Regardless of which filters you choose, always store them properly when they are not being used. Many come with padded storage boxes.

Finally, a quick tip for using color filters. It can be a hassle to screw a filter into an eyepiece and then find that it doesn't produce the desired effect. To avoid this aggravation, simply hold each filter between your eye and the eyepiece and take a peek. After you find the best filter for the job, take the time to screw it into place for extended viewing.

Color filters can make noticeable differences when viewing the Moon and planets. They won't transform your telescope into the eye of an interplanetary probe, but for those who take the time to study the planets carefully, the increase in subtle planetary detail can be amazing. ■

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616 Color Filter System f/416, 1616-XT	695
616A Color Filter System f/216	695
520 Electronic Relay f/201, 208, 216, 416, 1616	94.95
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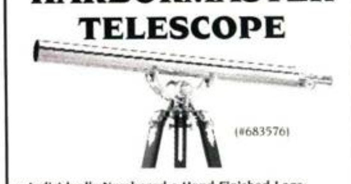

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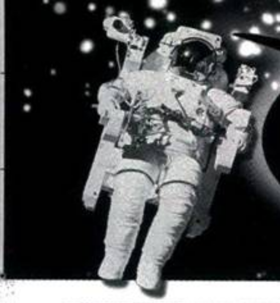

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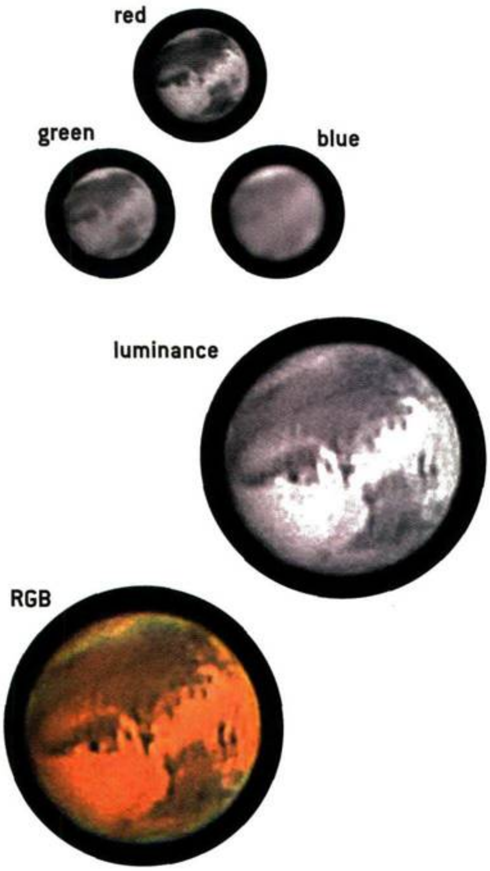
ASTROPHOTOGRAPHY

Use digital technology to produce the very best images of Mars. /// BY DON PARKER

Imaging the Red Planet

This month, Mars's close approach presents a fine opportunity for amateur astronomers to produce detailed images of our neighbor in space. When Mars nears a favorable opposition, its apparent size grows to greater than that of Saturn's globe. It appears as a tiny world with ocher deserts, dusky surface markings, polar ice caps, and clouds.



PUTTING THE PIECES TOGETHER in a CCD image involves combining red, green, and blue images to provide the "chrominance," or color of the image. Sometimes an unfiltered image provides the "luminance," or detail. The advantage of taking luminance images is that the exposures required are much shorter than those taken through color filters. The images above were created by Ed Grafton of Houston, Texas, who employed a Celestron 14-inch SCT with an SBIG ST6 cooled CCD camera and eyepiece projection. Meridiani Sinus is the dark feature just to the right of center. Chryse Planitia is the desert region to the left of center.

Mars is also a dynamic world with constantly changing meteorology, seasonal waxing and waning of its polar caps, varying reflectivity of albedo features — and, of course, the occasional dust storm.

Students of the Red Planet need to document such activity for as much of its apparition (the period when Mars is observable) as possible, not just around the date of opposition, which is August 28. This presents a problem, since much of the time the planet's apparent size is small. Recording detail requires high magnifications that make image quality very sensitive to the vagaries of turbulence in our atmosphere. Visual observations are most valuable then, because the eye can detect detail — during fleeting moments of atmospheric steadiness (called "good seeing") — that would be impossible to capture in photographic exposures of even one or two seconds. Over the past decade, however, a new technology has arisen that permits ground-based astronomers to obtain images of Mars rivaling (and sometimes even exceeding) what the eye perceives — digital imaging.

Beating the seeing

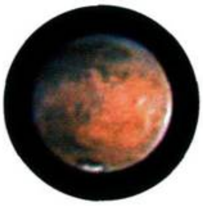
The main advantage of digital detectors for planetary imaging is that they produce acceptable results with much smaller image sizes than are required when using conventional photography. This means exposure times can be reduced, minimizing the deleterious effects of our atmosphere. We can beat the seeing!

Some basics

To understand this, keep two rules in mind. First, *the image size at the sensor depends on only one thing: the effective focal length (EFL) of the telescope.* An 8-inch f/10 system will produce exactly the same image scale as a 20-inch f/4 scope. The EFL of both systems is 80 inches. If the apparent diameter of Mars is 20 arcseconds (20"), its linear diameter can be calculated by multiplying its apparent size by the EFL and then dividing this result by 206,265 (the number of arcseconds in a radian). For example: linear size = (20" x 80 inches)/206,265" = 0.008 inch.

The image of Mars would be a tiny point of light at the focus of these telescopes. How can the image size be increased? One way is to mortgage your house and buy a large, long-focus instrument. Another way is to somehow make your present optical system appear longer. For most of us, the second alternative is more palatable — increase the EFL by employing some sort of projection system.

The second cardinal rule in imaging is that *the exposure time is inversely proportional to the square of the focal ratio.* This is where long focal length scopes must pay the piper. To get an image of the same brightness, the 8-inch f/10 telescope requires an exposure *6.25 times longer* than the 20-inch f/4 (100/16). This is a real advantage of short focal length telescopes.



THIS DETAILED IMAGE of Mars was made on April 3, 1999, by Maurizio DiSciullo of Coconut Creek, Florida. He used his Excelsior Optics 10-inch Newtonian reflector and a Starlight Express HX-516 cooled CCD camera with eyepiece projection at f/48. Note the tiny summer North Polar Cap at the bottom of the 14" disk. Solis Lacus is near the top. The dark streak below Solis Lacus is the western end of the Valles Marineris. Numerous white clouds are also visible.

Image scale and resolution

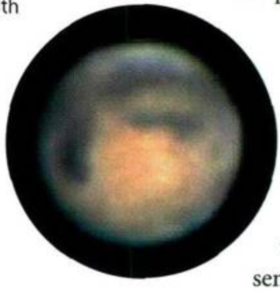
Even with very fine-grained film emulsions like Kodak Technical Pan 2415, the minimum image size of a planet at the film plane should be 0.1 inch. Because of this guideline, it's difficult to obtain high-quality Mars images when the planet's apparent diameter is less than 10". Increasing the image scale requires inordinately long exposures and, even then, minor atmospheric turbulence causes major distortions in the images.

With digital sensors, however, the image's size takes a backseat to resolution. For most amateur telescopes a good rule of thumb is that the minimum image scale should be around 0.25" per pixel. Satisfying the Nyquist sampling theorem, which requires two discrete measurements per resolution element, yields a resolution of 0.5" in the final image. For Mars, imagers can increase the image scale, or "oversample," to as small as 0.1"/pixel. With planetary details like lines or dots against a bright background, the "theoretical telescopic resolution" is often exceeded both visually and with electronic imaging.

Using modern CCD chips, today's amateur can produce images of Mars with 1/12 to 1/20 the exposure times required with film. High-quality Mars images that required focal ratios of 200 with film can be produced at f/50 with a CCD camera, reducing the exposure by a factor of 16. Indeed, now we have "beat the seeing" to a great extent and can image Mars with modest instruments even when the planet measures only 4" in apparent diameter.

Go figure

With electronic imaging, we don't need laborious calculations to compute image scales and appropriate projection systems. Because the image appears almost instantly on the screen, the setup can be altered quickly if necessary. It's advantageous, however, to have an idea where to start. A quick method for calculating the resolution is to multiply the pixel size in microns by 205 and divide this product by the EFL in millimeters. A telescope with an EFL of 8,200mm using a CCD camera with 10-micron pixels would produce an image scale of 0.25"/pixel — ideal for most planetary imaging. Multi-plying image scale by the number of pixels in the length or height of the chip will reveal the field of view of that chip. This is nice to know, since it is somewhat embarrassing to get set up and discover that only part of the planet will fit in the field!



USING THE AFOCAL TECHNIQUE, this Mars image was taken by Tim Parker and the author on June 5, 2001, through a 6-inch Newtonian reflector at 366x and a Nikon Coolpix digital camera. The image is a composite of 24 0.125-second exposures. The South Polar Cap is only slightly visible at the top. Syrtis Major is near the left limb. The "inverted pipe" of Sabaeus Sinus and Meridiani Sinus crosses the disk just above the center.

An EFL of 8,200mm equals nearly 27 feet. Few amateur telescopes have focal lengths this long. To achieve this resolution, the telescope's EFL must be increased by one of three methods.

Using a Barlow lens is the easiest way to increase image size. The EFL becomes the product of the scope's focal length and the Barlow's magnification factor. Since the camera's sensor is somewhat farther away from the lens than an eyepiece would be, the magnification will be slightly higher, but for most Barlows this is negligible.

THIS BEAUTIFUL MARS IMAGE taken by Mike Davis of Houston, Texas, on July 3, 2001, with a 3Com HomeConnect Web Cam and a Celestron 11-inch SCT. Negative projection with a 2.5x Tele Vue Powermate was employed. Images were stacked and processed with Astrostack and Paint Shop Pro. The South Polar Cap (top) and the bluish North Polar Hood (bottom) are visible. The dark feature near the left limb is Meridiani Sinus. The Chryse plain is the light region at the center of the disk.

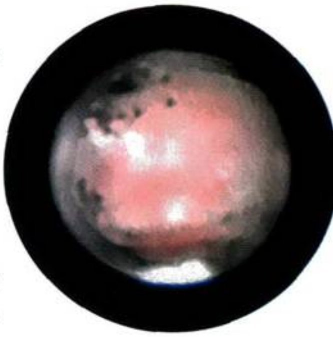
Some negative lens systems, such as the 5x Powermate, significantly increase enlargement over their given magnifications. Such devices are supplied with documentation for precise calculation of magnification.

Eyepiece projection permits much greater magnification than is usually possible with a Barlow lens alone and is the method of choice when CCD cameras with relatively large pixels are employed. In such a case, the eyepiece acts as a projection lens to focus the planet's image on the sensor, which is some distance (P) from the eye lens. The resulting image magnification (M) also depends on the eyepiece's focal length (f): $M = (P/f)-1$

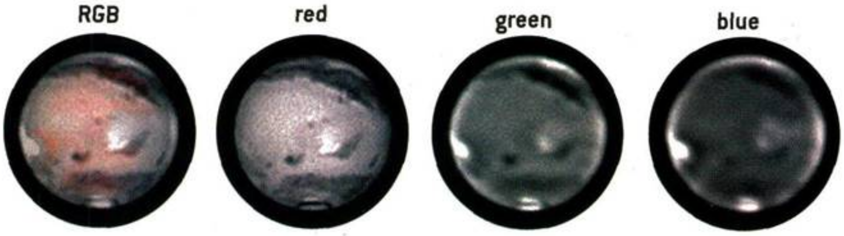
For example, if a 25mm eyepiece were placed 100mm from the sensor it would give a magnification factor of $(100/25)-1 = 3$. An 8-inch f/10 telescope would then be an f/30 system, with an EFL of 8 x 30 = 240 inches. If a camera with 10-micron pixels were employed, this system would produce an image scale of 0.34"/pixel.

Any good-quality eyepiece will work with this technique. Many planetary imagers employ microfiche projection lenses that are designed for presentations and have excellent color correction. These inexpensive lenses are available in a wide range of focal lengths. This allows the same setup to be used for many different-sized subjects.

The afocal technique is ideally suited for digital cameras without removable lenses. The camera is focused at infinity and held squarely against the telescope's eyepiece.



DETAIL AS SMALL AS 0.16 arcsecond (50 miles given the distance of Mars when this image was taken) stands out in this image. This number actually exceeds the theoretical resolution of the telescope. The image was taken by the author through a Stansbury 16-inch Newtonian reflector on February 20, 1995. He used a Lynxx-PC CCD camera, employing eyepiece projection, which increased the focal ratio to f/43. The very dark oval feature near the upper left (southeastern) limb is Solis Lacus. Note the bright North Polar Cap (bottom) and numerous water-ice crystal clouds over the Tharsis volcanoes across the center of the disk.



HIGH-RESOLUTION MARS IMAGES show various details in this set taken by the author on April 24, 1999, with a Lynxx-PC cooled CCD camera and a Stansbury 16-inch Newtonian. Eyepiece projection yielding f/43 was used. The red, green, and blue images were combined to produce the color image. The summer North Polar Cap is at the bottom with a "cold front" cloud coming off of it. The bright cloud near the center is an orographic cloud over the Elysium Volcanic Shield. The image to the right has been processed to show the mysterious "Syrtis Blue Cloud," which lies on the right limb.

The EFL is the product of the telescope's magnification and the camera lens's focal length. A telescope/eyepiece combination yielding 200x and a 25mm camera lens will have an EFL of 200 x 25 = 5,000mm.

Digital cameras

In the last few years, hand-held digital cameras have become popular and affordable. Like camcorders, they have the advantage of being useful for events such as family snapshots — making their purchase more tolerable to an astronomer's spouse. Using the afocal technique, many amateurs have produced stunning images of the Moon and planets.

The camera's focus and exposure settings should be controlled manually. You'll need an electronic (or cabled) shutter release to minimize vibration. Vignetting, the cutoff of the image toward the edge of the frame, is also a problem. Some cameras produce so much vignetting that it is impossible to acquire even a planet's image. Less expensive cameras with smaller aperture lenses and less optical zoom range are often preferable. The idea is to closely match the lens's aperture to the exit pupil of the eyepiece. Adapters that attach camera to eyepiece are available for digital cameras; the camera can also be mounted on a tripod and placed in position.

The main advantage of digital detectors for planetary imaging is that they produce acceptable results with much smaller image sizes.

Video cameras

These can produce excellent images of Mars. The simplest of these are color or black-and-white surveillance-type cameras. These sensitive and compact devices are usually employed with Barlow lens projection. Most have jacks that permit output to a monitor and/or a VCR. Taped images can later be fed into a computer for stacking and processing via video frame-grabber software. To avoid burning out (overexposing) the martian disk, it is essential that the camera have manual adjustments for signal gain and brightness.

With black-and-white cameras, try imaging Mars through a red (Wratten #25 or #23A) filter. These cameras are usually very sensitive to red and infrared light, so exposure times will not suffer appreciably, and there will be a marked increase in contrast between the planet's light and dark regions. With color cameras, a yellow filter (#15) produces very pleasing results.

Consider a little-used alternative: Camcorders with nonremovable lenses can image with the afocal technique. If your telescope's mounting is not rigid, use a tripod to avoid vibration. There are adapters for mounting camcorders to oculars, but make sure there is additional support lest the camera's weight cause damage.

If possible, use a digital format to record your videos. Images from your recordings can then be easily loaded and processed in your computer. Digital images are also much cleaner and considerably more quantitative than film.

Web cams

These small, inexpensive devices are revolutionizing planetary imaging. Their chips require only moderate magnification, so a Barlow is often all that is needed. They do require a computer and some software to process the images. Once the camera is in place and linked to the computer, the color balance and exposure time are adjusted, and a brief video run is saved to disk. The best images (frames) can then be selected, stacked, and processed. Freeware programs like Registax carry out this procedure automatically and can produce beautiful Mars images. Some programs even permit images to be calibrated. Video files do require a great deal of hard disk space. Two hundred images can consume more than 200 megabytes! Individual frames can be grabbed "on the fly," using the "acquire" functions of programs like Paint Shop Pro.

Stacking images

Noise is inherent in all electronic systems. A major component, thermal noise, is random and imparts a grainy, salt-and-pepper appearance to the image. Cooling the chip reduces thermal noise by about 50% for every 6° C drop in temperature. CCD cameras are usually cooled by thermoelectric coolers sometimes aided by water-cooled heat exchangers. Web cams, digital cameras, and video cameras are usually not cooled, so other methods must be found to reduce the noise.

One way is to increase the signal — the good stuff in the image — by increasing the exposure time. Noise will also increase but not as much. The amount of noise is proportional to the square root of the signal, so if you increase the exposure to quadruple the signal, the noise will only double and the signal-to-noise ratio (S/N) will improve by a factor of two. Take care, however, not to overexpose so much that the pixels become saturated. This will cause the polar caps, clouds, and bright

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Don Parker *is executive director of the Association of Lunar and Planetary Observers.*

desert regions to become misshapen blobs devoid of detail. Longer exposures also make the planet's image more susceptible to the deleterious effects of seeing, so a balance must be struck.

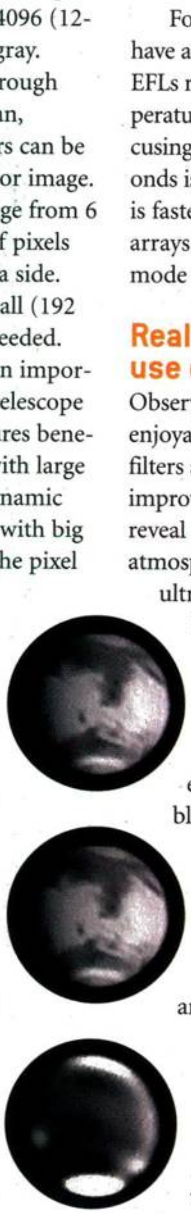
Stacking, or averaging, individual images will also improve the S/N ratio. This is a normal routine for users of uncooled cameras. When stacking planetary images, take care to avoid smearing due to the planet's rotation. Fortunately, the martian rotation rate is slow enough to permit averaging many images taken over a 5 to 6 minute period without smearing.

Cooled CCD cameras

These low-noise cameras often produce high-quality images of Mars. Their chips are monochrome, yielding from 4096 (12-bit) to 65,000 (16-bit) shades of gray. Three individual images taken through red, green, and blue (RGB) or cyan, magenta, and yellow (CMY) filters can be combined to produce a single color image.

Pixel sizes in these devices range from 6 to 24 microns, and the number of pixels varies from 192 to over 2,000 on a side. For imaging Mars, a relatively small (192 to 320 pixels) array is all that is needed. The choice of pixel diameter — an important decision — depends on the telescope employed: Relatively small apertures benefit from smaller pixels; cameras with large pixels generally have increased dynamic range and can be used effectively with big telescopes. The trick is to match the pixel size to the EFL.

Exposures, or "integration times," should be as long as the seeing permits, but the pixel saturation levels should be kept below 80% so that fine details are not burned out. Higher focal ratios can be employed with Mars than with the other outer planets, because Mars has a surface brightness nearly four times that of Jupiter. Keep in mind that with extended objects it is surface brightness, rather than apparent magnitude, that counts.



INFRARED REJECTION FILTERS are valuable, as demonstrated here. The top image was taken in red light through a Wratten #25 filter. Much surface and polar cap detail is visible. The center image was obtained through a dark blue #47 filter without infrared rejection. Due to infrared light freely passing through the filter to the infrared-sensitive CCD chip, the image looks as if it were taken in red light. The bottom image was taken through a #47 filter with infrared rejection. Numerous clouds are visible with little surface detail. These images were taken by the author on December 31, 1994 with a Stansbury 16-inch Newtonian and a Lynxx-PC cooled CCD camera and eyepiece projection at f/50.

Focusing

Focusing with CCDs is critical, and there is little room for error. An electric focuser is essential. Schmidt-Cassegrain telescope users should employ a rack-and-pinion or Crayford focuser to avoid troublesome lateral image shifts that sometimes occur.

For focusing, the CCD camera must have a rapid download time. At the high EFLs required for imaging Mars, slight temperature variations demand frequent refocusing. A download time of less than 3 seconds is a highly desirable feature. Download is faster with smaller chips, but larger arrays can often be used in a "subframe" mode to facilitate more rapid focusing.

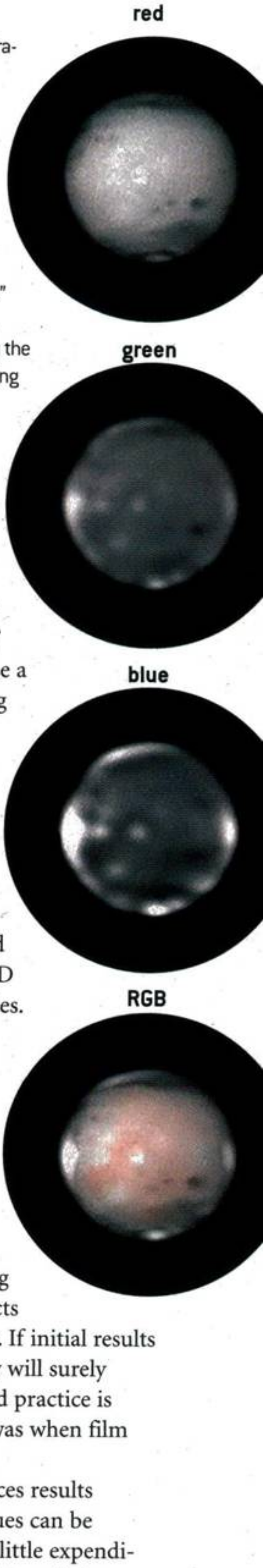
Real men (and women) use color filters

Observing and imaging the planets is more enjoyable with color filters, but with Mars filters are almost essential. Red filters improve contrast, enhance fine detail, and reveal dust clouds. Because the martian atmosphere is usually opaque to blue and ultraviolet light, observations through blue filters reveal water-ice clouds and limb hazes that would otherwise be difficult to detect.

Note that even with the new generation of CCD chips with enhanced sensitivity, exposures in blue light are frequently quite long, since Mars is not particularly bright in blue.

Still, you can salvage valuable cloud data by averaging several short exposures, thus reducing noise and producing a cleaner image.

When selecting filters, check with the camera's manufacturer to see which match your chip and which have infrared blocking capability. Many green, blue, and even ultraviolet filters pass infrared wavelengths that are detected by most CCDs. So instead of images of beautiful clouds over volcanoes, you wind up with only surface details. If you use filters with this "red leak," you really should purchase a separate infrared-blocking filter to stack with your color filters.



COLOR FILTERS PRODUCE dramatically different results with Mars. Details on the surface are distinct through a red filter. Through a blue filter very little of the surface is seen, but clouds and hazes are revealed. Note the famous "Domino Clouds" over the Tharsis volcanoes. These images were taken by the author on April 29, 1999, using a Meade 16-inch SCT, a Lynxx-PC cooled CCD camera, and eyepiece projection yielding f/43.

It is most important to calibrate your images with flat fields, dark subtraction, and bias correction. These are simple procedures and are described in most CCD camera manuals and guides.

Practice, practice, practice

Even with modern technology, Mars can be a difficult subject for the novice, so it's a good idea to hone one's imaging techniques on easier objects like the Moon and Jupiter. If initial results are less than optimal, they will surely improve with practice, and practice is much easier now than it was when film was the only medium.
Electronic imaging produces results immediately, and techniques can be adjusted "on the fly" with little expenditure of time or money. With sufficient practice and attention to detail, today's amateur astronomers should be able to produce wonderful images of our beautiful neighbor, Mars.

Submit your Mars images by sending them to gallery@astronomy.com.

This new line of telescopes by Meade looks like a classic but is 21st century all the way. /// BY STEVE EDBERG

An upgraded classic

On a dark night, an observer seeing a Meade LXD-55 Schmidt-Newtonian for the first time could be forgiven for thinking he had been transported in time back to the 1960s. Forty years ago, the most common commercial telescope was probably the 6-inch f/8 Newtonian on a clock-driven (110 Volts AC), pier-supported equatorial mount. Larger sizes were much less common.

Today, Meade offers a range of telescopes, updated mechanically and optically, for observers in the 2000s. With the LXD-55, the classic lines are all there, but our observer wouldn't take long to realize this instrument is clearly a telescope of the 21st century. The new LXD-55 line boasts 6-inch, 8-inch, and 10-inch models. *Astronomy* received the 8-inch SN-8 to test for this review.

The mount

Starting from the ground up, Meade's German equatorial mount (GEM) sits atop an adjustable aluminum tripod, a far cry from the fixed-height pedestal of the '60s. The legs are tipped with rubber pads (more on those later) so the tripod can be used on pavement or the ground. An accessory tray on top of the leg-spreaders holds the battery power supply (eight D cells in a package) and any eyepieces, filters, etc., you might want to stash there.

The beauty of an equatorial mount is that it can track the sky automatically once it is set up correctly. "Correctly" means the polar (right ascension, or R.A.) axis of the mount must be aligned parallel with Earth's rotational axis. Most instruction manuals (and Meade's is no exception) say to level the top of the tripod first. While this isn't a necessity, it does make alignment and adjustments easier. The mount has opposing T-handle screws, which allow the observer's latitude to be set with an indicator on the side at the pivot.

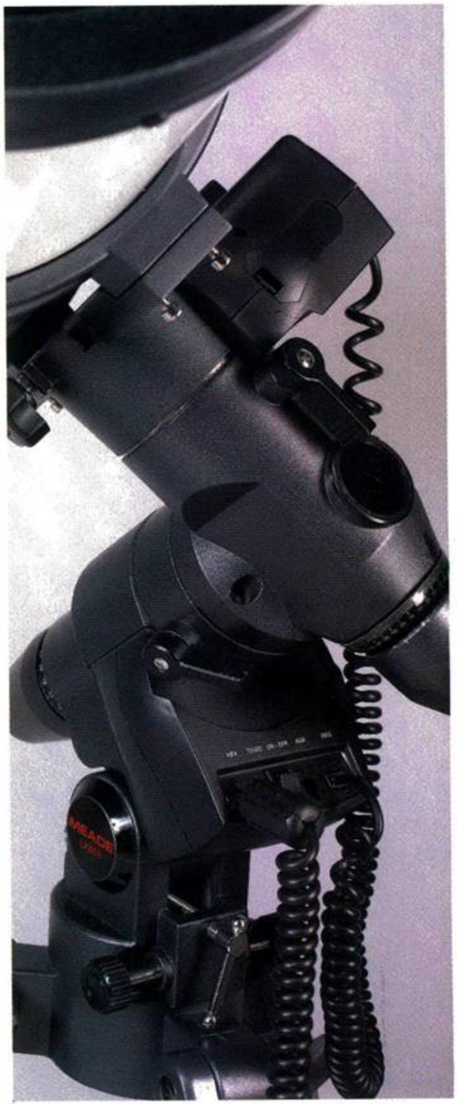
Next, the polar axis of the equatorial head must be aimed northward, as close to the north celestial pole (near the North Star, or Polaris) as possible. Opposing thumbscrews can be used for fine adjustments to align the mount toward geographic north. Meade, to its credit, suggests that the observer not spend lots of time perfecting the alignment if only casual observing is planned.

For more exact polar alignment, use the illuminated polar-axis telescope in the GEM; follow the instructions supplied. Finding Polaris in the polar-axis telescope was a bit challenging because the eyepiece was in focus either on its internally etched alignment pattern or on the star — but not on both at the same time.

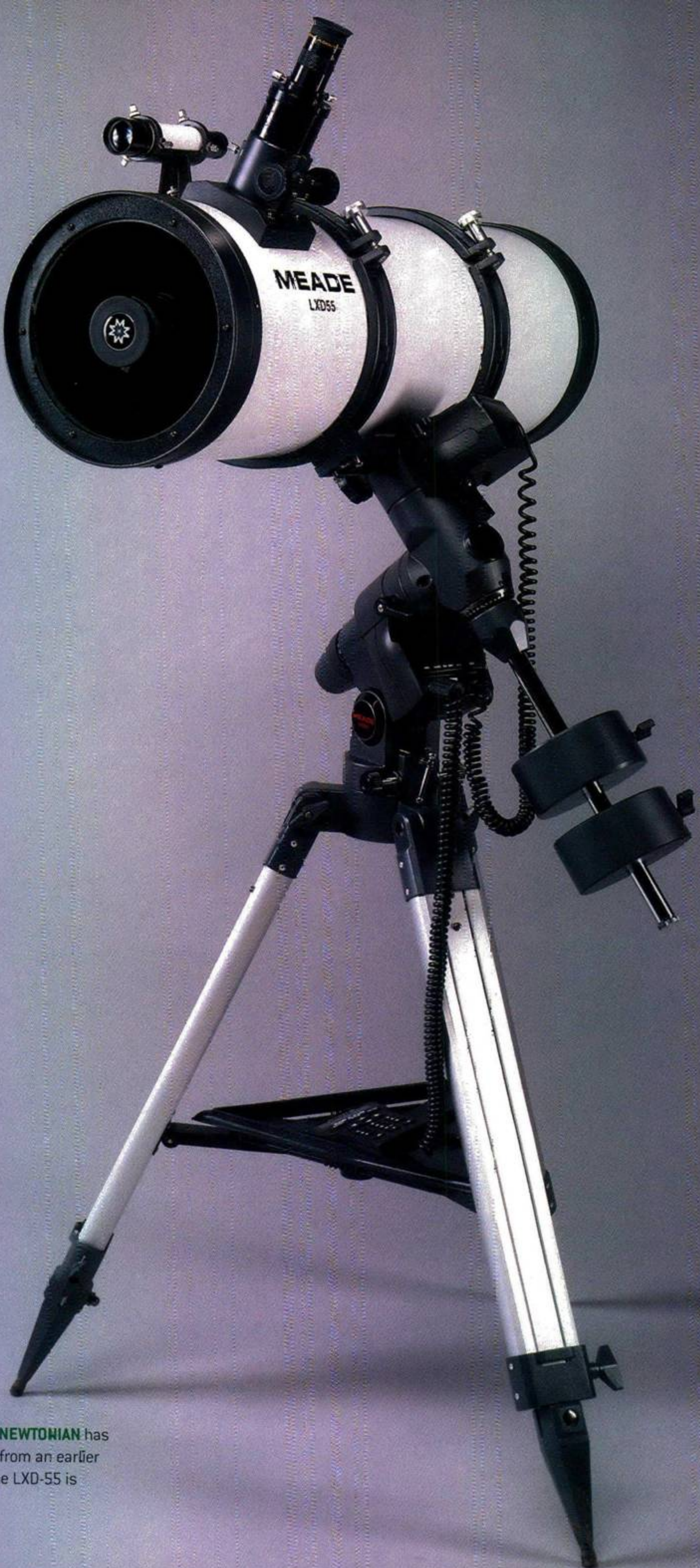
The right ascension and declination axes are motorized for hand control or computer control. As with many mounts, the clamps to lock the axes are on moving parts and can be hard to find until you get used to their placement.

Balancing

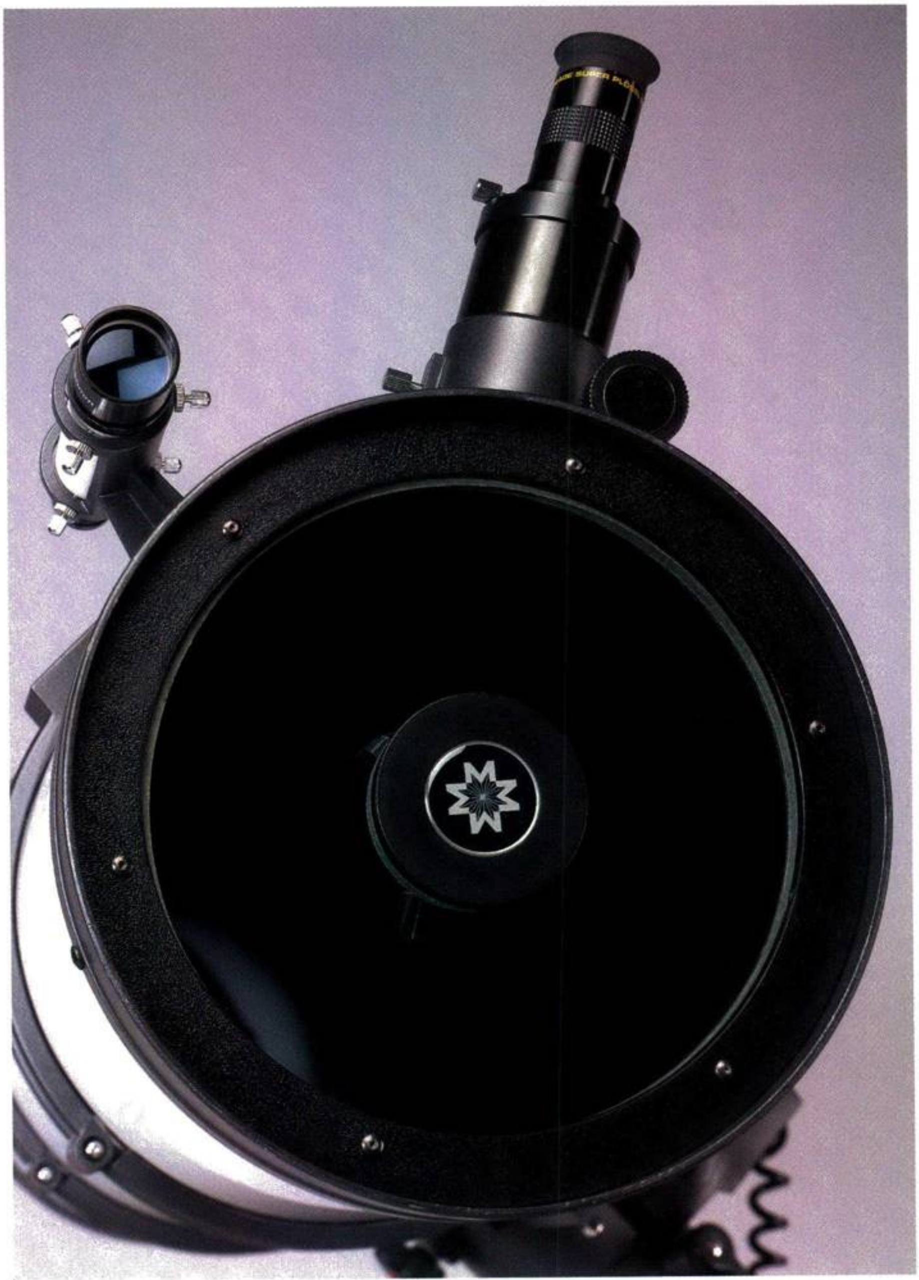
The LXD-55 comes with a pair of counterweights that slide until locked in place. A thumbscrew at the end of the declination shaft keeps them from slipping off, a good safety feature. When the telescope is first set up, position the declination axis horizontally. After carefully releasing the polar-axis lock, you balance the telescope by sliding the counterweights into the right positions. Then re-lock the right ascension axis and release the declination axis. To balance the scope in this axis, loosen the thumbscrews on the telescope cradle to allow the tube to slide fore/aft until balance is achieved, then re-tighten the cradle screws.



THE GERMAN EQUATORIAL MOUNT tracks celestial objects accurately.



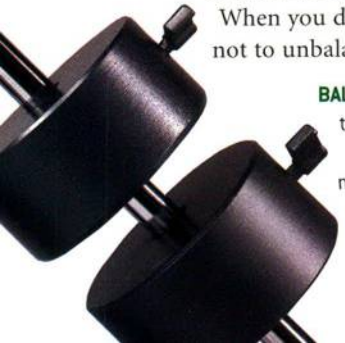
THE LXD-55 8-INCH SCHMIDT-NEWTONIAN has the classic look of telescopes from an earlier era. The aluminum tripod of the LXD-55 is light, adjustable, and sturdy.



THE FRONT CORRECTOR PLATE clearly identifies the Schmidt-Newtonian optical design of the LXD-55.

I found that both axes had a fair amount of friction. This is normal in a new scope, but I was never sure how closely I managed to balance the two axes.

One nice feature of any cradle-mounted Newtonian is being able to rotate the tube and move the eyepiece to a more convenient viewing position. When you do this, be careful not to unbalance the tube.



BALANCE IS CRITICAL, and two large counterweights help you maintain it even when using heavy eyepieces or accessories.

THE POLAR-AXIS TELESCOPE within the German Equatorial Mount has an illuminated reticle to help fine-tune your alignment.

Optics

The telescope's optics are special. The design is Schmidt-Newtonian, something I have rarely seen in a production telescope. The Newtonian design uses a primary mirror and a second, "diagonal" mirror to send the image out the side of the tube. The innovation is the Schmidt corrector plate that permits this telescope to be photographically fast — f/4 — while providing pinpoint star images across a wide field of view. This has great value for visual observers, especially for wide-field observations and images of deep-sky objects. This is not a telescope designed for high-magnification observations of planets or double stars.

The usual poor winter seeing found in southern California kept me from pushing the telescope to its optical limits with star and planet tests, but a Ronchi ruling showed nice straight lines — a good thing — across the primary mirror. The out-of-focus "donuts" were similar both inside and outside focus, and the in-focus images of stars and Jupiter were crisp. I did notice a weak internal reflection while centering on very bright objects. The Ultra High Transmission Coatings, which improve the performance of the telescope, are a deep blue-violet.

When storing the telescope, make sure you keep an eyepiece or plastic cover in the focuser. Even with the limited use this new scope received, I saw a tiny bit of dust on both the primary and diagonal mirrors. This amount will in no way degrade the performance of the telescope, but you want to reduce dust as much as possible. Likewise, in the telescope I tested, some of

Steve Edberg *is executive director of the Riverside Telescope Makers Conference, Inc., and has been observing with numerous telescopes since the 1960s.*

the paper liner on the Schmidt corrector cell was slightly off-center, obstructing ⅛" of the aperture on one side. You won't notice this small obscuration.

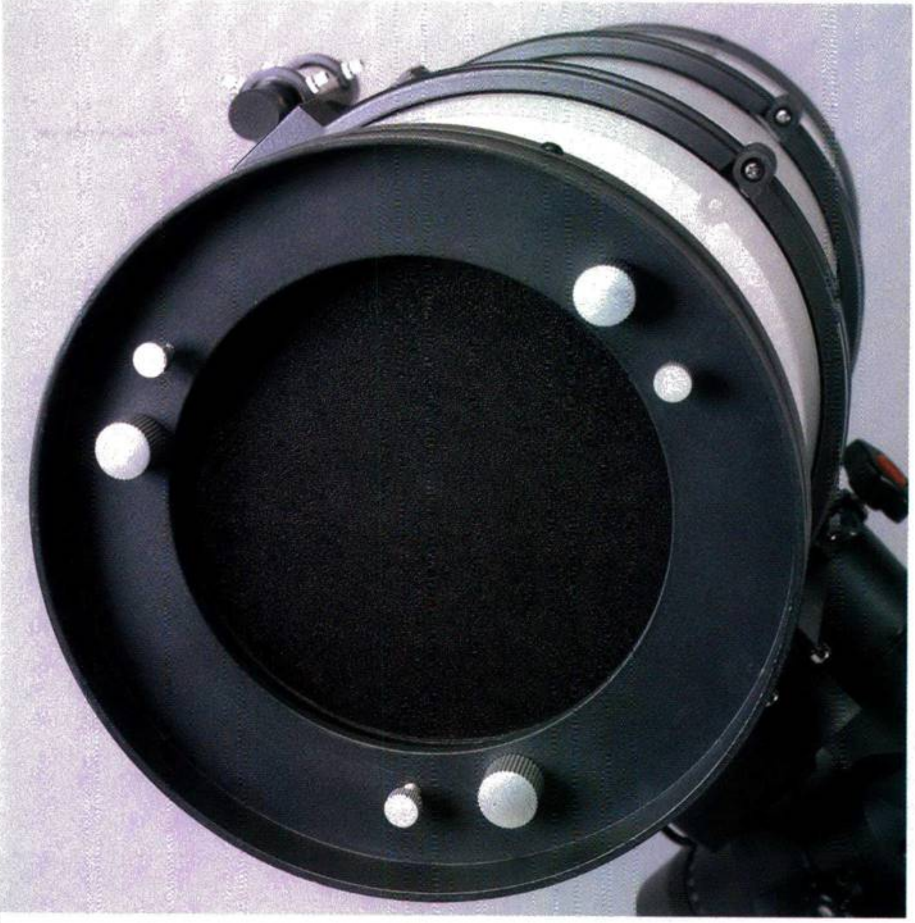
Mechanical considerations

The rear mirror cell has a solid backing, common in commercial reflectors nowadays. This improves the dust seal but slows down the telescope's equalization to ambient temperature when you bring it from a warm room into the cold night. Therefore, plan your evening session accordingly and, if possible, take the scope outside an hour or more before you start observing.

This telescope is less pricey than many of today's models, so major fittings on the assembly, including the focuser, are either plastic or "pot" metal. I was pleasantly surprised to see that adjustments and instructions were provided to ensure the optical axis of the telescope is parallel to the R.A. axis of the mount. This is critical to serious observers, and I've never seen this adjustment offered before. Kudos to Meade!

The weakest point of most telescopes, especially those in this price range, is the mount. The LXD-55 mount, even when all the hardware is tightened down, has a loose feel. I tapped on various places to find where vibrations were generated, but couldn't hone in on any one offending part. The rubber foot pads damp vibrations twice as quickly compared to when foot pads aren't used. On a positive — and somewhat surprising — note, when the foot pads are used, the tripod's height doesn't affect the damping time.

The manual provides instruction on how to point the telescope both by hand and by motor. I found a slight delay before the tracking motor kicks in. This means an object centered in the field of view will drift a bit off-center before tracking starts. You can correct this by slightly overshooting the center of the field of view, having the drive start just as the object drifts into the center. This happens even when using the Autostar computer.



THE REAR MIRROR CELL is sealed but still has the standard adjustments for collimating the optics.

THE TELESCOPE WILL TRACK MORE ACCURATELY if the top of the tripod is level during setup.

Autostar

The real power of this drive system comes with the Autostar computer controller. Step-by-step instructions begin with the basic features and gradually teach users how to use the more complicated bells and whistles. I would have liked step-by-step "getting started" lists as appendices, as these would have speeded things up once I was familiar with the system. Apparently, the manual writer had a momentary lapse while preparing the instructions to set the polar home position: the R.A. and Dec. axes are interchanged in the description for getting the telescope aimed north with counterweights down.

When I got the system working, it would always put the object into the finder's field of view, and sometimes in the telescope's as well. Since the finder is 6x30mm, it doesn't have the aperture to help center the fainter Messier objects, much less quasars — none brighter than 13th magnitude — in the Autostar's mem-

AUTOSTAR
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THE BRAIN OF THE SYSTEM is the hand paddle, which contains the Autostar computer controller. This device allows true go-to capability. The paddle also contains thousands of target objects and, with an optional cable, it can connect to your personal computer to create or download even more lists.

ory. If I was not precisely on Polaris, I know I was close. I don't think the computer/mount combination should have been missing objects by that much.

The generalized accuracy of this computerized system may make the LXD-55 a telescope for a slightly more experienced observer who knows what he or she is looking for. The same may not be true for relatively new observers. For example, if a new observer is looking for M86, deep in the Virgo Cluster of galaxies, will he know which of the faint fuzzies in the field of view is M86? Probably not.

The Autostar contains thousands of objects and also has the capability to return a position on any object you've found. It will compute the current position of a planet (based on the date and time) and direct the telescope there. You can scroll through descriptions of cataloged objects. The Autostar will even take you on a tour of the night's best objects, a fine way for someone new to get acquainted with the sky. Or you can download other tours or create your own.

The Autostar also has useful utilities. It can calculate eyepiece magnifications, compute the times of sunrise/set, moonrise/set, eclipses, meteor showers, equinoxes, and solstices. It even allows you to set a timer so you won't miss a celestial event.

The SN-8 comes with a Meade 26mm Super Plössl eyepiece, adapters for 2" and 1¼" eyepieces, and a T-adapter for camera T-rings. It is a complete package for someone getting started in astronomy, although I encourage the additional purchases of a good star atlas and binoculars. Participation in a local astronomy club can also be a good investment.

Computerized telescopes are one way for observers to find celestial objects, but owning one still requires the observer to learn the sky and its denizens. That learning is what makes astronomy even more appealing, since it opens the universe to closer and more awe-inspiring study. ■

Meade LXD-55 Schmidt-Newtonian Telescope

6-inch Model SN-6	$695 list
8-inch Model SN-8	$839 list
10-inch Model SN-10	$995 list

Prices vary depending on electronic or computerized hand control and choice of optical coatings.

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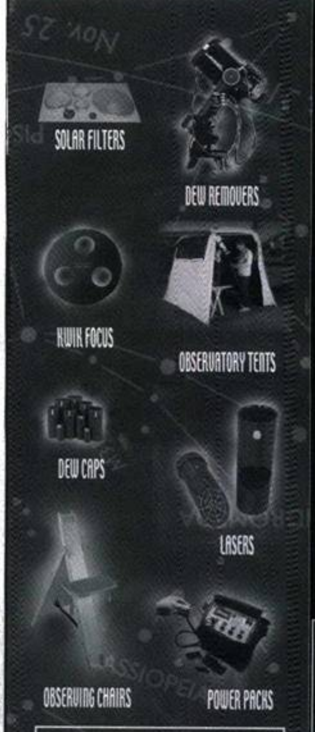

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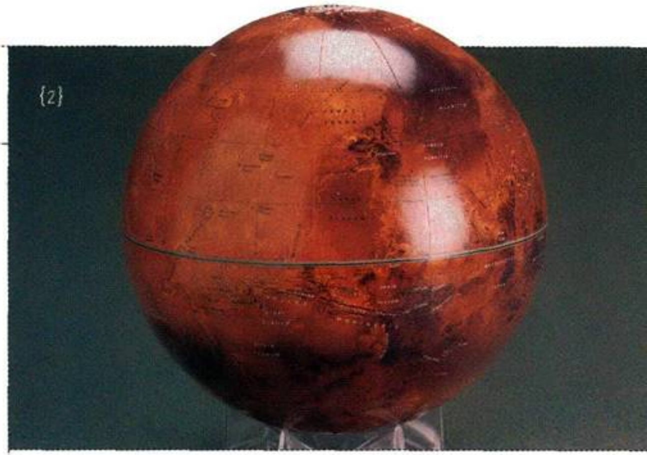

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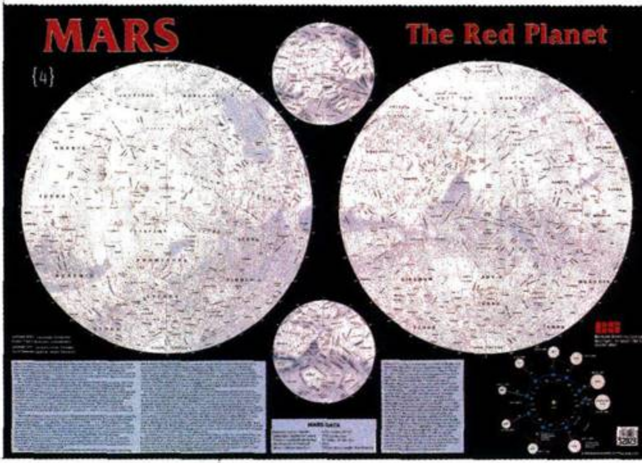

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4. Mars map

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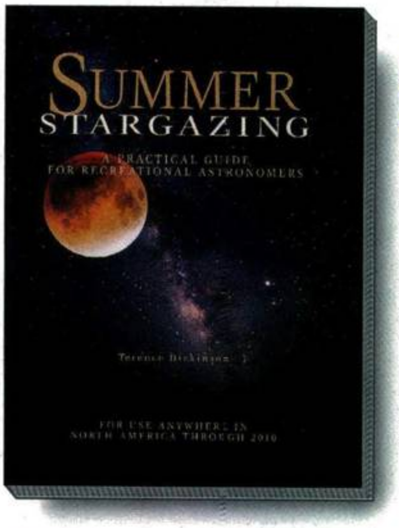
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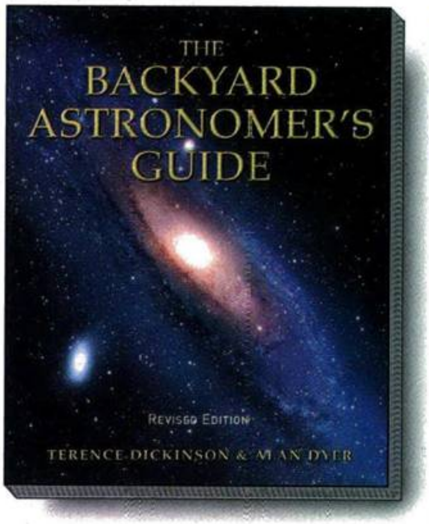
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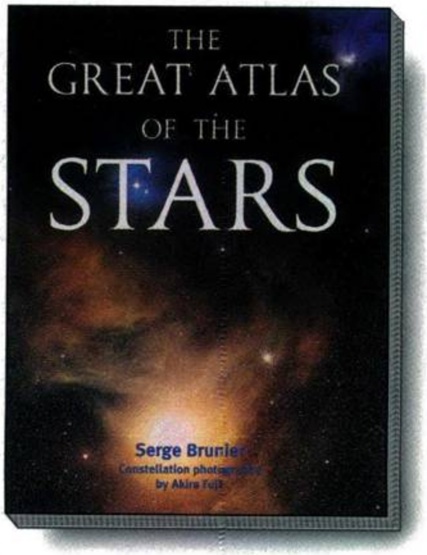
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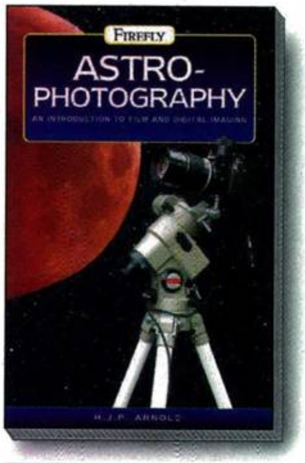
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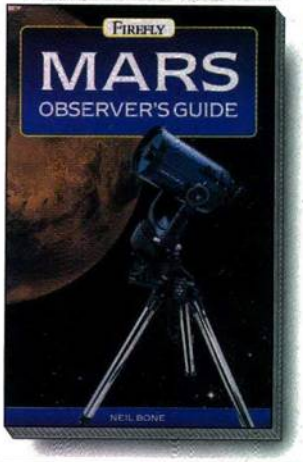
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Origins: The Quest for our Cosmic Roots

Tom Yulsman, 384 pages, Institute of Physics Publishing, Bristol, England, 2003; ISBN 0–7503–0765–X; softcover, $21.99.

The grand adventure of this book begins in Horseshoe Canyon, Utah. There, Yulsman, clutching a handful of sand, reflects on each grain's incredible journey from the birth of hydrogen and helium in the Big Bang to the Utah stream nearby. The canyon connects him to the cosmos; for the rest of the book, he connects the cosmos to the reader.

Starting with the mind-bending concepts of relativity and quantum mechanics, Yulsman demonstrates a remarkable ability to express complex, counterintuitive ideas with straightforward language and insightful analogies. From the first instant after the Big Bang, when the universe was as small in relation to a proton as today a proton is to New Jersey, to the current profusion of life on Earth, he emphasizes the crooked intellectual path by which theories are created, challenged, modified, and recreated.

He introduces us to the very human scientists responsible for those theories as they bound up the summit of Mauna Kea to watch the sunset or "cook" the stuff of interstellar gas into pre-biotic goo. He paints science as the human activity it is, at one point describing an argument between two astronomers about the evolution of star-forming molecular clouds. "Watching the two of them go at it at five in the morning, I wonder whether I've misunderstood how new scientific knowledge is created," he writes. "Maybe the traditionalists who emphasize a neat, orderly method consisting of experiments, observation, and testing are missing the intangible but more important dimension — a *personal* dimension. . . . The traditional picture of cool, detached observers drawing pure conclusions from raw data just doesn't fit what I'm seeing here in the control room of the Canada-France-Hawaii Telescope. " Yulsman reveals not only the scientists' intensity and excitement, but also their sense of wonder at how the universe works.

In the last few pages, readers can experience this fascination through the researchers' own words. Astronomer Sandra Faber describes our planet as "a tiny mote in a hostile void," and Yulsman argues that it would be tragic if humans, crowded onto the surface of this mote, made ourselves extinct. Thus, he divulges a motive for writing the book — his hope that the more we understand about the amazing events that led to our existence in the cosmos, the more reverence we will have for this world and its inhabitants.

— AILEEN A. O'DONOGHUE *is an associate professor of physics at St. Lawrence University in Canton, New York. She studies radio galaxies and stars.*

Echo of the Big Bang

Michael D. Lemonick, 232 pages, Princeton University Press, Princeton, New Jersey, 2003; ISBN 0–6911–0278–3; hardcover, $24.95.

In 1927, a Belgian priest named Georges Lemaître suggested the universe began as a primeval atom that exploded and expanded into the cosmos we know today. Two years later, astronomer Edwin Hubble found supporting evidence for Lemaître's Big Bang model: Most galaxies are rushing away from us — and each other. About a decade after that, physicists Ralph Alpher and Robert Herman theorized the explosive birth of the universe should have left another imprint — faint radiation dubbed the cosmic microwave background. They also predicted, with remarkable accuracy, this radiation should have cooled to about three degrees above absolute zero. In 1965, the microwave background was finally detected by two scientists at Bell Telephone Laboratories.

Echo of the Big Bang is the exciting story of the quest to detect, record, and understand this relic radiation from the creation of the cosmos. In the book, *Time* magazine's senior science writer, Michael D. Lemonick, gives a concise but complete background on the birth of cosmology in the early 20th century. He covers everything from Hubble's observations of the expanding universe to the theoretical predictions of the afterglow. But the focus of the text is on NASA's latest mission to measure this radiation — the Wilkinson Microwave Anisotropy Probe (WMAP), launched in 2001. Among the probe's first astonishing findings, announced this past February, was the most accurate measurement yet taken of the age of the universe — a ripe 13.7 billion years.

Echo of the Big Bang is well written and nicely paced, and in addition to the science coverage, readers get an inside view of NASA and the social interactions (sometimes strained) of the scientists who work there. The book's main weakness is its dearth of images — it contains only a few black-and-white pictures. In a number of places, the discussion would have benefited from an image or line diagram, such as when Lemonick describes the cosmic microwave background in terms of its constituent frequencies and intensities — when these are plotted against each other, the result looks like a camel's hump. He discusses the geometry of space without accompanying illustrations, and the black-

and-white projections showing subtle temperature differences in the radiation across the sky would have had much more impact in color. Overall, however, the book is a wonderful summary of modern cosmology that highlights the importance of the WMAP mission for our understanding of the universe. — **JENNIFER BIRRIEL** *teaches physics and astronomy at Morehead State University in Kentucky.*

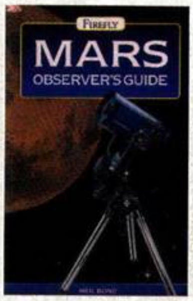
On the Shoulders of Giants: The Great Works of Physics and Astronomy

Edited by Stephen Hawking, 1,266 pages, Running Press, Philadelphia, 2002; ISBN 0–7624–1348–4; hardcover, $29.95.

The giants referred to in the title are Copernicus, Galileo, Kepler, Newton, and Einstein. Each is represented by a complete work in English translation: *On the revolutions of the heavenly spheres* (1543); *Dialogue on the two chief world systems* (1638); *Harmonies of the world*, Book V (1616); *Mathematical principles of natural philosophy* (1687); and a collection of papers on relativity (1922).

Unfortunately, those responsible for the research behind the book don't have strong shoulders on which to stand. In the "note on the texts," only one title, Newton's *Principia*, is free from error in spelling or date. The "life and work" of Copernicus contains ideas that have not been seen in respectable writing on the history of science for generations: Aristotle held men's minds in thrall for over a thousand years; the Roman Catholic Church accepted the astronomy of "the Egyptian" Ptolemy as gospel; Copernicus proposed his system as a calculating device; the Church burned Bruno for his astronomical opinions. A section on Galileo contains similar nonsense and ends with the valuable summary, "Galileo's contributions to humanity were never understated."

The dust jacket advertises that the giants' texts have never been published together before. True. Apart from the relativity papers, however, all the texts, indeed the very same texts, appear in *Great Books of the Western World* (54 volumes, Encyclopaedia Britannica, Chicago, 1952). The publication of *Great Books* coincided with the establishment of the history of science as an academic subject in American universities. Fifty years of solid scholarship, much of it devoted to these giants, followed; none of it is mentioned in this new volume. Neither did the book mention translations of several texts published since 1952, notably *On the Revolution of Heavenly Spheres* and *Principia*. Standing on the shoulders of Alexandre Koyré, Stillman Drake, I. Bernard Cohen, Owen Gingerich, Noel Swerdlow, and other authorities on the giants' texts, a graduate student could have provided readers with a broader and longer view of the works and their place in history. — **J. L. HEILBRON** *is a senior research fellow at the University of Oxford's Worcester College and editor of* The Oxford Companion to the History of Modern Science, *published this June.*

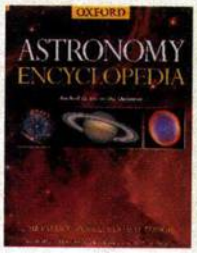


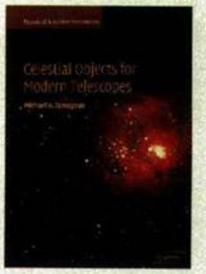
Mars Observer's Guide

Neil Bone, 160 pages, Firefly Books, Buffalo, New York, 2003; ISBN 1–5529–7802–8; softcover, $14.95. Just in time for this month's close-up view of Mars comes a pocket guide jam-packed with observing tips and general information on the Red Planet. The book's eye-catching layout draws readers in with its excellent use of color illustrations, sketches, and photographs. But the guide does not sacrifice substance for style — the pithy, well organized text includes practical viewing tips and ephemerides for the martian apparitions this year, as well as in 2005, 2007, and 2008.

Astronomy Encyclopedia

Edited by Sir Patrick Moore, 464 pages, Oxford University Press, New York, 2002; ISBN 0–1952–1833–7; hardcover, $50. From Alfvén waves to the Zeeman effect, this beautifully illustrated reference provides more than 3,000 clear and concise definitions of astronomical phenomena and personae. Edited by astronomy popularizer Sir Patrick Moore, the book contains photographs, diagrams, and star charts (by expert mapper Wil Tirion) by the hundreds, as well as tables on meteor showers, exoplanets, the nearest and brightest stars, and more. It's useful as either an introduction to or a refresher on a wide range of topics.



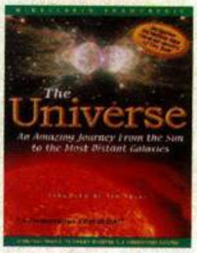


Celestial Objects for Modern Telescopes

Michael Covington, 268 pages, Cambridge University Press, New York, 2002; ISBN 0–5215–2419–9; softcover, $30. If you're looking for a roadmap on observing the night sky, this may well be the book for you. While it contains little information on equipment (that's covered in the companion volume, *How to Use a Computerized Telescope*), it helps readers pick the best observing sites and targets (organized by both type and month). It also provides background on the Messier, Caldwell, and Herschel catalogs, among others, and it explains how to decipher star names and charts.

The Universe

Universe Productions, Menlo Park, California, 2002; DVD, $24.95; VHS, $19.95. Are cloudy skies keeping you from viewing celestial wonders? Then sit back on the couch and gaze at the solar system and distant galaxies with *The Universe.* Available on DVD and VHS, this journey through space features video and images from Hubble, SOHO, and other space-based observatories. With succinct narration and an orchestral score, *The Universe* will entertain as well as inform. As a bonus in the DVD version, California-based astronomers Alex Filippenko, who studies supernovae, and Karel Schrijver, an expert on the Sun, help demystify the universe.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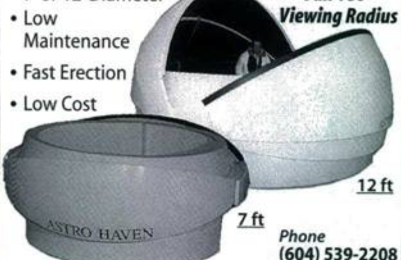

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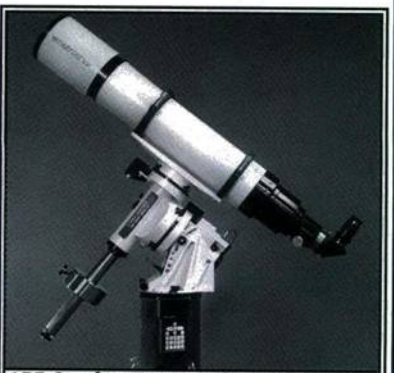

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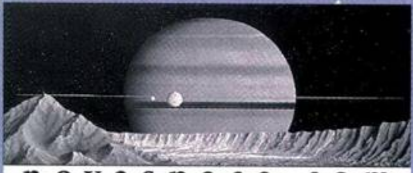

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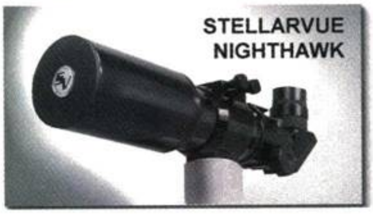

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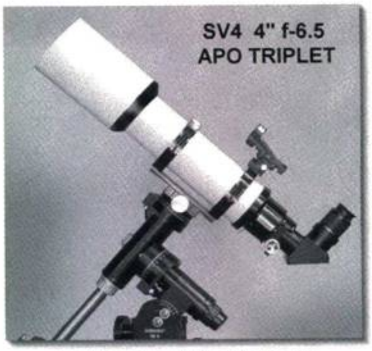

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Oregon Star Party

Ochoco National Forest, about 50 miles east of Prineville, Oregon. For more information, visit http://www.oregonstarparty.org/.

08.29.03–09.01.03

Arunah Hill Days

Arunah Hill Natural Science Center, Cummington, Massachusetts. For more information, visit Arunah Hill's website, http://www.arunah.org/. ■

CONTACT INFORMATION

Please submit club announcements four months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Add your events to our on-line calendar at http://www.astronomy.com.

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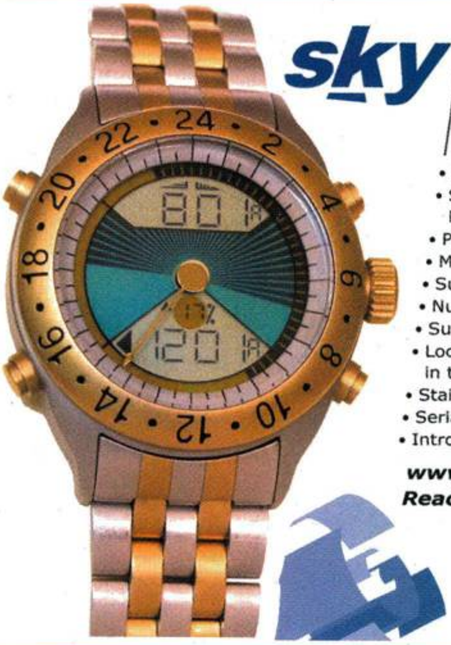

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{ FURTHER READING }

RESOURCES

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MARS ROVER

WEB — NASA provides a detailed look at the Mars Exploration Rover (MER) mission at its website, http://mars.jpl.nasa.gov/mer. For information on the MERs' instrumentation, including several videos of rovers at work, click to http://athena.cornell.edu. NASA keeps up-to-date information on all its past, present, and future science-exploration satellites at http://spacescience.nasa.gov/missions.

WHAT IS MARS TRYING TO HIDE?

BOOKS — Take a virtual trip to Mars in William K. Hartmann's new book, *A Traveler's Guide to Mars* (Workman, New York, 2003), which includes full-color photographs and four gatefold maps.

ARTICLES — *Astronomy* has run several Mars articles recently, including "Mysteries of the martian poles" by Peter Thomas in the March 2003 issue and another on recent martian discoveries, "Red Planet Renaissance," by William K. Hartmann in the July 2000 issue.

WEB — NASA's Jet Propulsion Laboratory (JPL) is an excellent source of information on each planet, with links to past, present, and future missions, as well as easily digested fact sheets on planetary science. Its page on Mars is at http://mars.jpl.nasa.gov, and its page on the Mars Global Surveyor mission is at http://mars.jpl.nasa.gov/mgs. An on-line book on Mars published in 1996 is located at http://www.uapress.arizona.edu/online.bks/mars/contents.htm. An amazingly clear and fascinating set of essays by Mike Caplinger of Malin Space Science Systems detailing how astronomers study Mars is listed at http://www.msss.com/http/ps/intro.html. Information from JPL on martian meteorites is at http://www.jpl.nasa.gov/snc, and an inventive "interview with a meteorite" that was put together by the American Museum of Natural History appears at http://www.amnh.org/rose/mars/od3.html.

MARTIAN CHRONICLES

BOOKS — Mars certainly ranks among the most popular planets, and it has the bibliography to prove it. For a good overview of our species' fascination with the Red Planet, check out *Destination Mars: In Art, Myth, and Science* by Martin Caidin and Jay Barbree with Susan Wright (Penguin Studio, New York, 1997) and *Mars: The Lure of the Red Planet* by William Sheehan and Stephen James O'Meara (Prometheus Books, Amherst, New York, 2001). For an in-depth look at how space missions have changed our perception — including many gorgeous pictures, some in 3-D — see *Mars: Uncovering the Secrets of the Red Planet* by Paul Raeburn (National Geographic Society, Washington, D.C., 1998). Of course, you can't go wrong heading back to the book that started much of the hoopla, *Mars* by Percival Lowell (Houghton Mifflin, Boston, 1895). Because the copyright on this book has expired, you can find the entire manuscript in several places on-line, including http://www.wanderer.org/references/lowell/Mars.

LUPUS AND NORMA

BOOKS — For those who are new to the southern sky, Milton D. Heifetz and Wil Tirion's *A Walk through the Southern Sky* (Cambridge University Press, New York, 2000) is an easy-to-use beginner's guide. The book helps its readers find the southern constellations and recounts the legends behind them.

Fans of *Astronomy*'s Celestial Portraits series will also enjoy David J. Eicher's *The Universe from Your Backyard* (Cambridge University Press, New York, 1988). This older, but still relevant, collection offers an account of must-see deep-sky targets. The book also includes some of the author's sketches of these challenging objects, assembled in an alphabetical, constellation-by-constellation arrangement.

See Mars at its best from the equator

August 17-27, 2003

Join *Astronomy's* editors for a once-in-a-lifetime view of the Red Planet from a suite of sensational locations this autumn. Mars will be at its best in more than 2,000 years and will be highest in the sky – and therefore showing the most detail – from way down South.

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Machu Picchu

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Lake Titicaca

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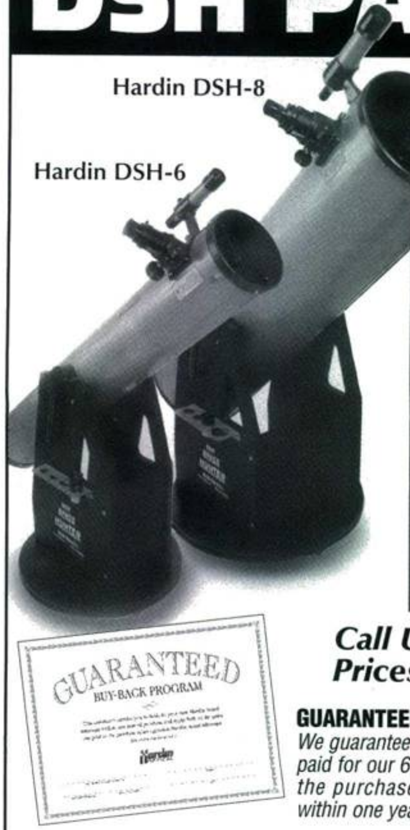

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OBSERVING MARS

BOOKS — For more information about Mars, read *The Smithsonian Book of Mars* by Joseph M. Boyce (Smithsonian Institution Press, Washington, D.C., 2002). Boyce, who was NASA's Mars exploration program scientist for 15 years, brings much insight regarding our exploration of the Red Planet. Another good, general book is *Mars: The Mystery Unfolds* by Peter John Cattermole (Oxford University Press, Oxford, England, 2001).

It is rare to find a book dedicated to the observation of Mars; however, the newly released *Mars Observer's Guide* by Neil Bone is a comprehensive guide written solely about viewing the Red Planet (Firefly Books, Buffalo, New York, 2003). Amateur astronomy guides also can help you along. *The Cambridge Encyclopedia of Amateur Astronomy* by Michael E. Bakich (Cambridge University Press, New York, 2003) is another good source.

WEB — Much great information about observing Mars is available through the Internet. One location stands out, though: the Association of Lunar and Planetary Observers site at http://www.lpl.arizona.edu/alpo. Click on the "Mars Section," and you'll find articles, observing forms, and lots of other information to make your observations of Mars the very best.

IMAGING MARS

BOOKS — For a good overview of CCD technology, try Steve B. Howell's *Handbook of CCD Astronomy* (Cambridge University Press, New York, 2000). Another excellent how-to reference on creating exceptional astroimages is *The New CCD Astronomy: How to Capture the Stars with a CCD Camera in Your Own Backyard* written by Ron Wodaski (New Astronomy Press, Duvall, Washington, 2002).

WEB — Damian Peach, an excellent Mars imager who resides in Tenerife, Canary Islands, maintains a website at http:/www.the-planets.co.uk/tpo/. ■

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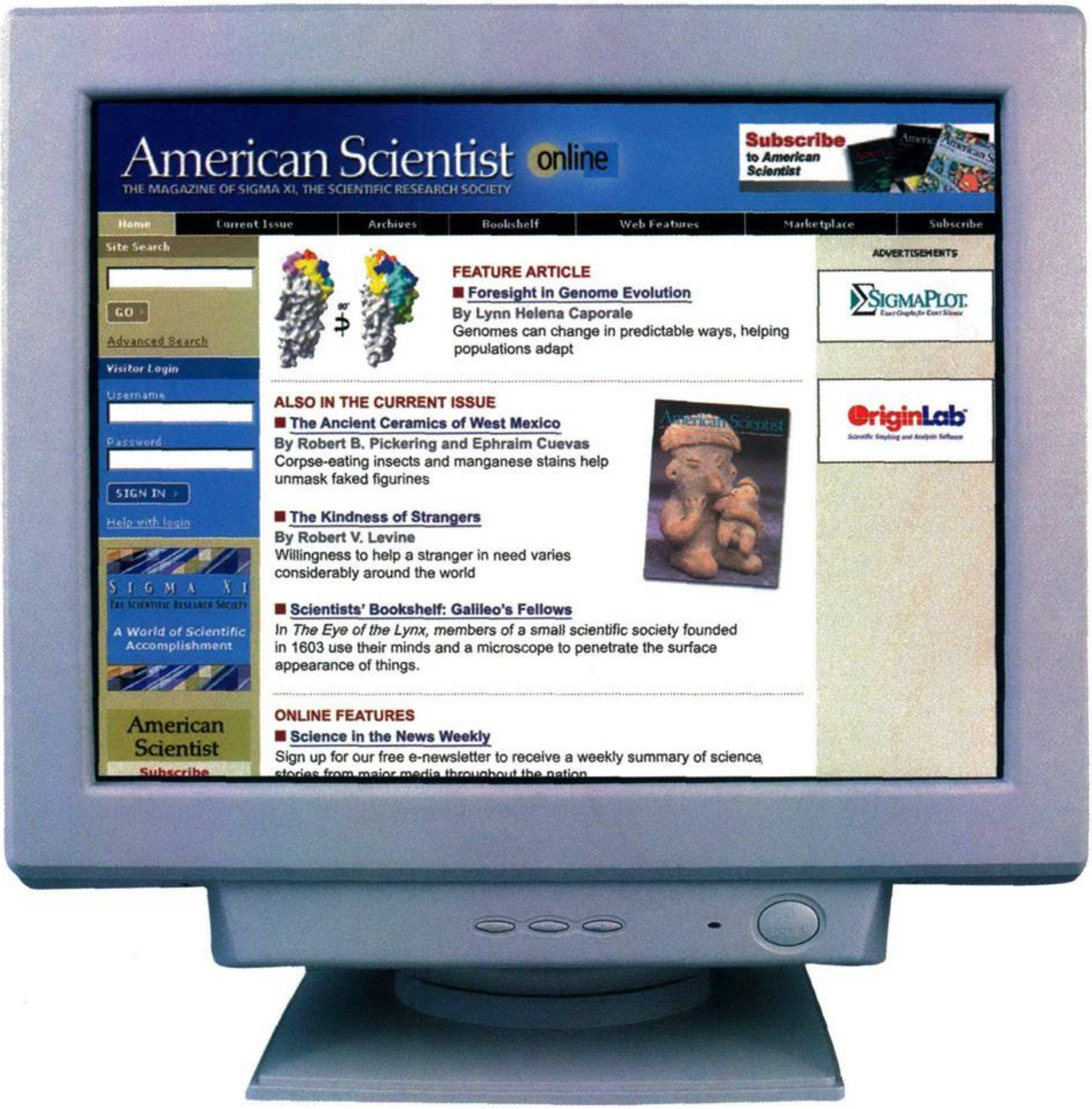
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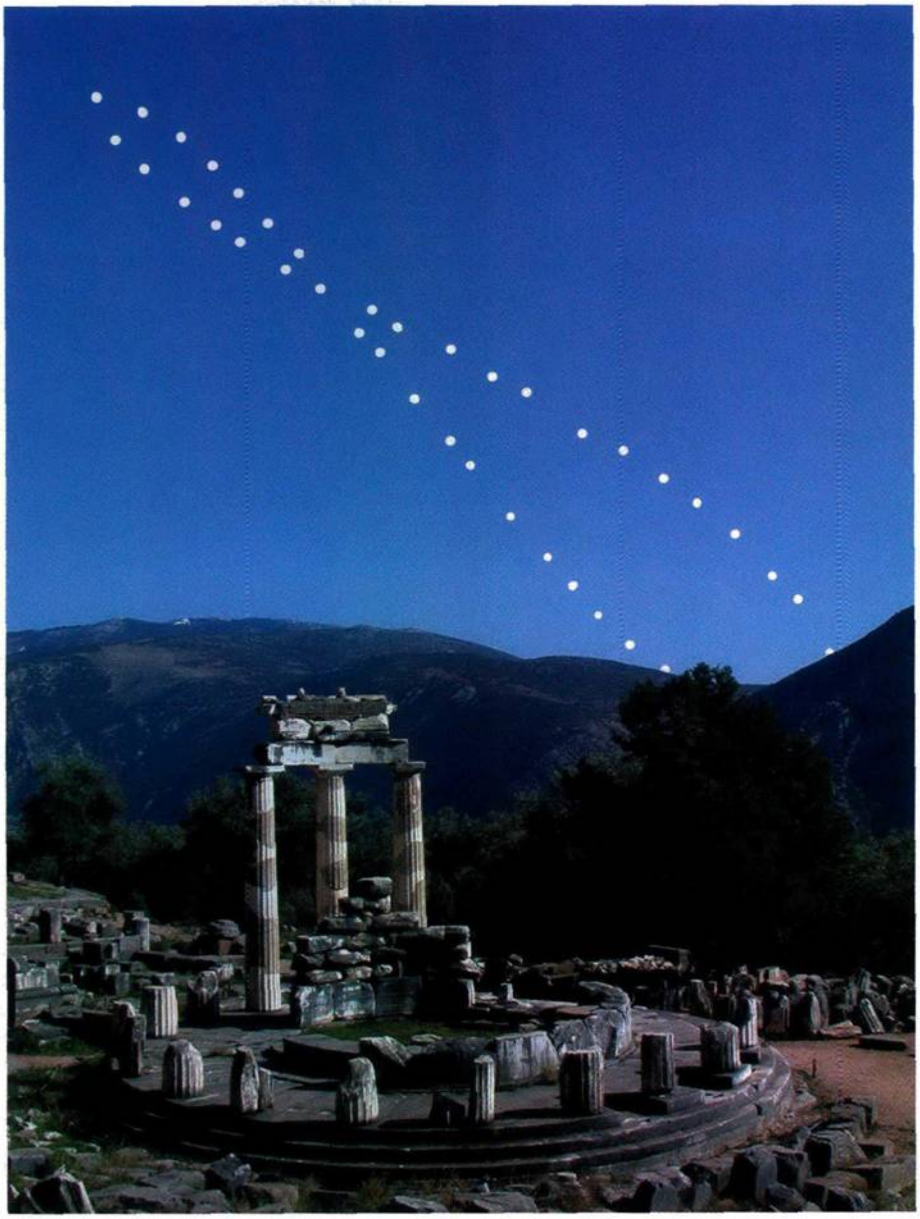
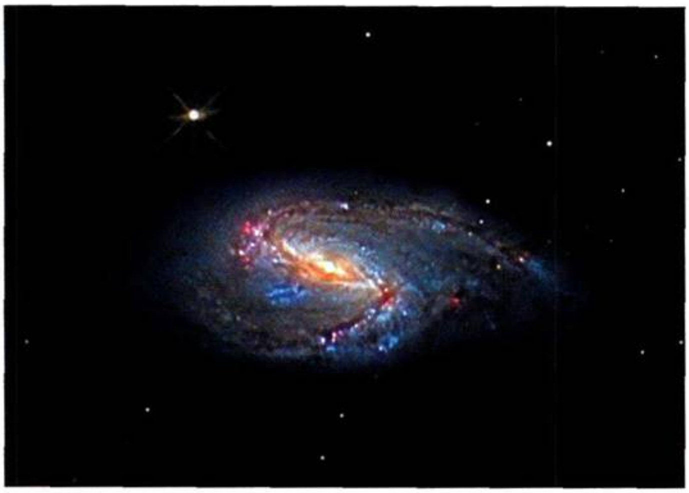
EARTH'S ORBIT

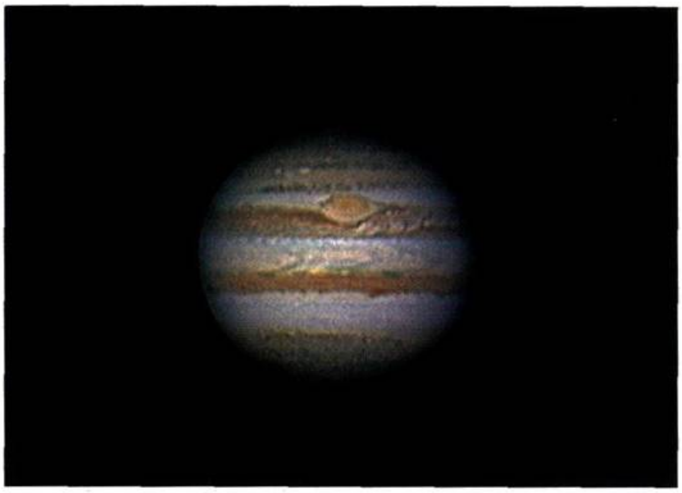
The analemma

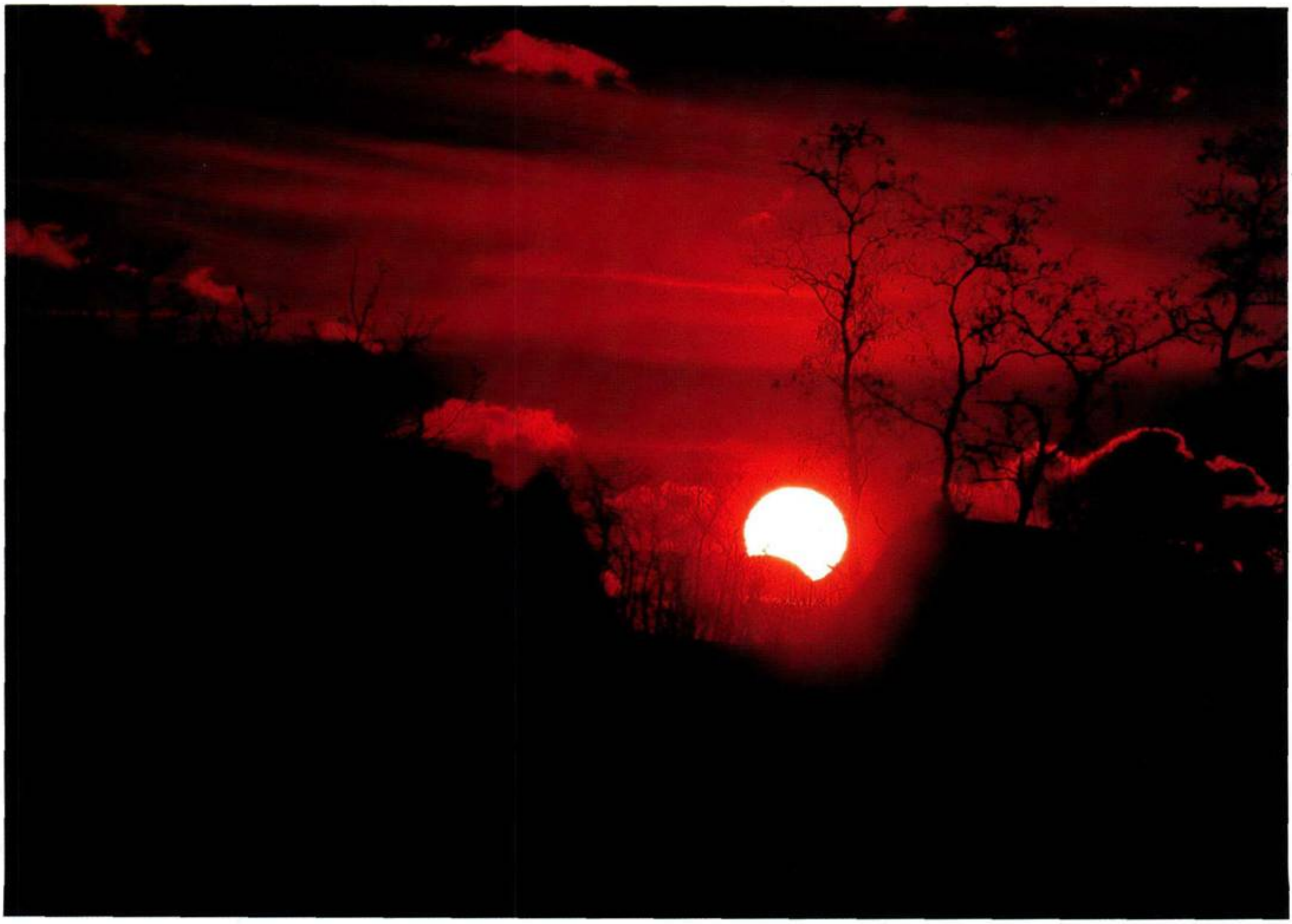
Astrophotographers love to image planets and the deep sky. Meteor showers keep them up all night long. And bright comets produce a veritable flood of images. Incredibly, astrophotographers have managed to capture only seven successful images of a solar analemma as a multi-exposure on a single piece of film. This fact should not come as a surprise, however, because a complete analemma takes nearly a year to image. An analemma is basically the figure-8 loop that results when you observe the position of the Sun at the same time each day over the course of a year. As a result of Earth's 23.5° tilt on its axis and its elliptical orbit around the Sun, the location of the Sun is not constant from one day to the next.



Left, **THE ANALEMMA** with the Tholos, Delphi, Greece [Canon A-1, 24mm lens at f/11, Fuji Super HQ 200 film, Baader ND-5 solar filter, 38 multiple exposures plus one foreground image, taken January 12 to December 21, 2002]
/// **ANTHONY AYIOMAMITIS**







Top left, **M66, A SPIRAL GALAXY IN LEO** [RCO 12.5-inch Ritchey-Chrétien at f/9, SBIG ST8XE, 60-minute luminance exposure plus 10 minutes each of R, G, and B] /// **RICHARD JACOBS**

Top right, **JUPITER,** the lord of the planets, with its Great Red Spot [10-inch Takahashi Mewlon 250 at f/27, Toucam Pro digital camera, taken March 17, 2003, in Singapore] /// **TAN WEI LEONG**

Above, **PARTIALLY ECLIPSED SUN SETTING** [Nikon 880 digital camera, 285mm lens with red filter, taken December 14, 2001, in Roanoke County, Virginia] /// **BOB SANDY**

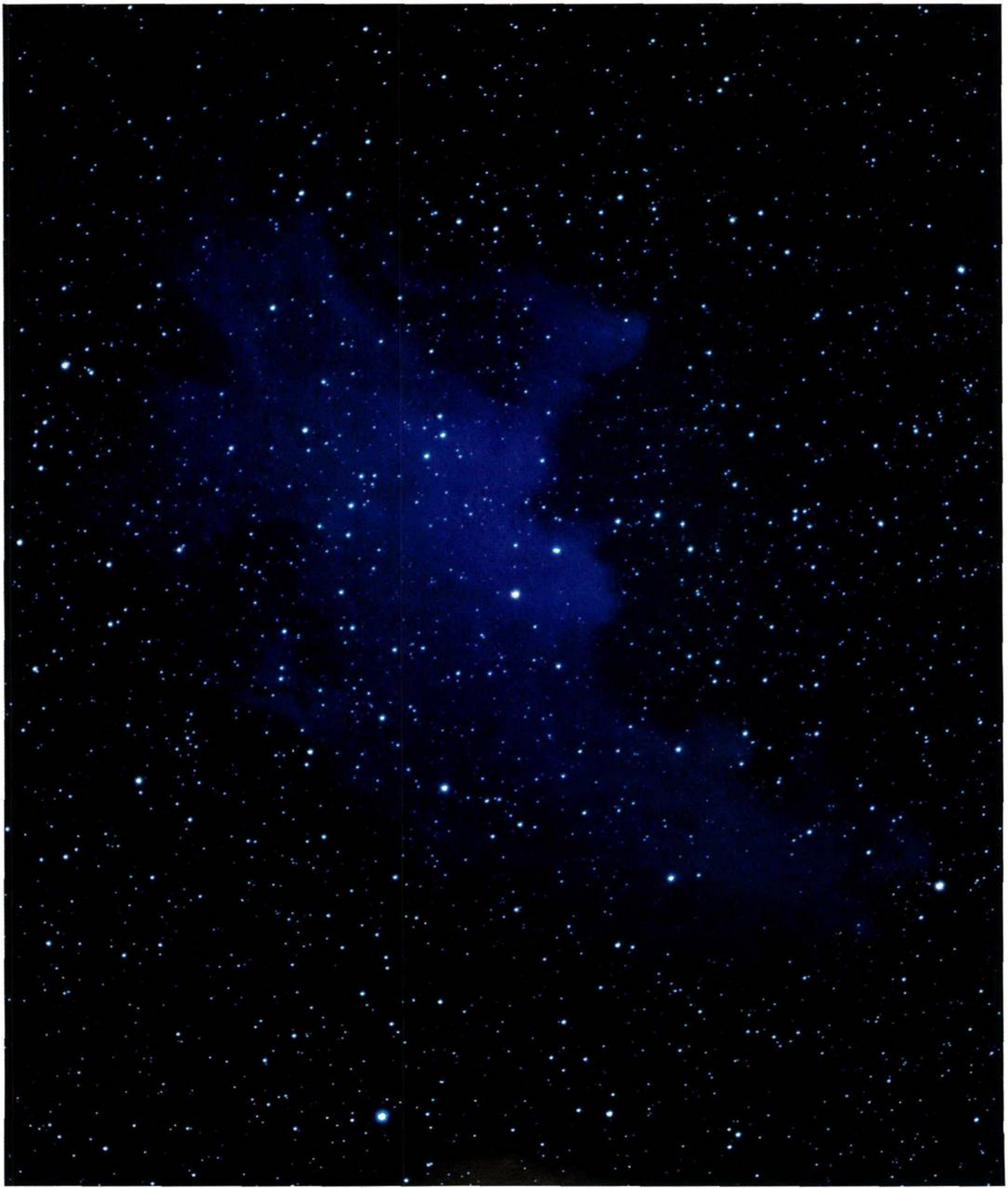
Send your photos to: ASTRONOMY Reader Gallery, P.O. Box 1612, Waukesha, WI 53187; e-mail to readergallery@astronomy.com.
Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.

Above, **THE RHO OPHIUCHI REGION** (AstroPhysics 4-inch f/6 refractor, 6x7 Pentax camera, PPF 400 film, taken in Forest Hill, California) /// **TONY AND DAPHNE HALLAS**

Top right, **THE WILD DUCK CLUSTER, M11** (Optical Guidance Systems 12.5-inch Ritchey-Chrétien at f/6, SBIG ST10E CCD, RGB exposures of 10, 10, and 20 minutes) /// **ROBERT GENDLER**

Bottom right, **THE NGC 3190 GALAXY GROUP** (Optical Guidance Systems 12.5-inch Ritchey-Chrétien at f/9, SBIG ST10E CCD, two-frame mosaic) /// **ROBERT GENDLER**

Below, **THE WITCH HEAD NEBULA** (4- inch Takahashi FSQ-106, Canon D60, 20 five-minute exposures, taken February 27, 2003) /// **MARK HANSON**



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